A LAND USE TRANSPORT INTERACTION MODEL FOR THE KANPUR METROPOLITAN AREA

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MARCH, 1989

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A Thesis Submitted
in Partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

by

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to the

DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

MARCH, 1989

to

Lekha

and

Devikrishna

C E R T I F I C A T E

This is to certify that the thesis entitled **A Landuse Transport Interaction Model for the Kanpur Metropolitan Area** submitted by Mr. **R Sathikumar**, in the partial fulfillment of the requirements for the degree of Master of Technology of Indian Institute of Technology, Kanpur, is a record of bonafied work carried out by him under my supervision and guidance. The work embodied in this thesis has not been submitted elsewhere for a degree.

March 7, 1989

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ACKNOWLEDGMENT

I take this opportunity to express my deep sense of gratitude to my guide, Professor S.P. Palaniswamy, who had initiated me into the problem and had provided the much needed active and effective guidance. His keen interest in this work, sincere advice and kind help in the moments of difficulty had been a regular source of encouragement to me.

I am grateful to Research Engineers Rajendra, and Valsala for their help.

My sincere thanks to Abraham, Anil Dubey, Goyal, Jaychandran, Jayakumar, Kanaujia, Nageshwar Rao, Pathak, Rajpal, Siva and Vishnupotty who helped a lot in one way or other during the course of completion of this work.

I am highly grateful to all teacher who taught me at IIT, Kanpur. I am thankful to my classmates Hari, Nishu, Sudip and Vishnu who made my stay here pleasant one.

Thank are due, to my parents, father-in-law and Anil.B who encouraged me to join this prestigious Institute of world class.

Sincere appreciation is expressed to Suresh for the neat typing and cooperation.

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ABSTRACT

Kanpur Metropolis consist of 221 chaks in all. Out of this, home-interview was conducted in the first 133 chaks by the project personnel of Transportation Engineering Project, IIT Kanpur. Depending on the socio-economic profile and geographical locations, the area under study has been categorized into 7 zones. The specific objective of this thesis is to develop a landuse transport model that is aggregated by socio-economic characteristics, purpose and mode group and which may be used in strategic planning studies for urban area in India.

Among the various transportation models available to predict the landuse and travel requirements the Lowry model is considered to be one of the eminently suitable models. The objective of this thesis is to simulate the landuse transport interaction with the data available for Kanpur Area Transportation Study, of the Transportation Engineering Project, IIT Kanpur. Lowry model has been calibrated to predict the landuse parameter of Kanpur.

A major effort has been made to determine the parameters of the Lowry model. Calibration includes the transport impedance functions for activities such as metropolitan, local and neighbourhood. Various functional forms have been calibrated which serve as alternative models for future use.

The calibrated model has been found to be capable of predicting the spatial distribution of different socio-economic activities in the Kanpur metropolitan area. The model has been

validated against the observed data in terms of level of employment in each area along with the household location in terms of residential areas. The model can be used to experiment the changes in landuse as a function of changes in transportation network and operating characteristics of various modes. Similarly, problems pertaining to restructuring activities of cities, in general, can be articulated in terms of their consequences for public utility requirements and other resources.

CHAPTER 1

INTRODUCTION

1.1 General

Planners have realized the importance of transportation effect on the urban spatial structure. Transportation facilities are generally expensive and long term investments. Very often they become inadequate because of failure to appreciate the relationship that exists between various activities, housing and their linkage by transportation. The realization of such interdependence has resulted in two major modelling operations being integrated together. The procedure adopted is to forecast landuse and population and compute travel requirements as a result of first, then revising the landuse and population allocations on the basis of the second. A transportation model is therefore linked with urban landuse model to make it interactive with transportation.

Landuse-transport planning procedure is capable of developing alternate urban planning strategies based on a large number of policy variables. An optimum planning solution for the urban system can be arrived at very quickly with the help of these models. They enable us to develop optimal transportation facilities for a given urban landuse pattern and provide an optimal arrangement of landuse to yield desired transport solutions.

Based on the socio-economic and topographical conditions a suitable procedure is suggested for modelling the landuse

transportation interaction. A pioneering model by Lowry [5] describes one of the best landuse allocation methodologies to estimate landuse distribution and the associated travel demand simultaneously. In addition,the structure of this model may be adopted relatively easily to the mixed landuse characteristics of Indian cities.

1.2 Models

A great deal of interest has been shown in the Lowry model by researchers in many parts of the world since its framework was first published in 1964 . The appealing characteristics of the Lowry model are its simple and easily understood casual structure and its adaptability to a variety of practical problems. Its users, particularly in Britain, have had great success in meeting requirements of regional and transportation planning agencies. Major changes and extensions to the Lowry model have been directed towards disaggregation of activities, constraints on activity allocation, calibration and evaluation techniques, zoning systems and network and the addition of dynamic features.

In general Lowry type models display certain characteristics that are common are given below:

(1) Partitioning of total employment into population serving or "retail" employment and a residual employment termed "basic".

(2) The causal system leads from basic employment to population serving employment, and

(3) The population serving employment allocation grows out of a

multiplier relationship applied to basic employment.

1.3 Functional Structure

The functional structure of the Lowry model is represented in figure 1·1 and can be described as follows:

A level and location of industrial activity (measured by basic employment) is estimated externally and provided to the model. From this level, the model derives its related population which is then allocated spacially over the area under study. It then derives the related requirement for service activities(measured by retail employment) and allocates them to service areas. Now from this level and location of service employment the model derives its dependent population related to the new employment force. Then this additional population is allocated, and at the same time demands for services, which in turn, create more jobs, and so on. The model iterates in this way until a stable solution is achieved for a given input of basic employees.

From this description, we can observe that the model performs two basic functions:

(1) The model derives dependent population and service employment

(2) Households and retail employment are allocated to zones of the area under study.

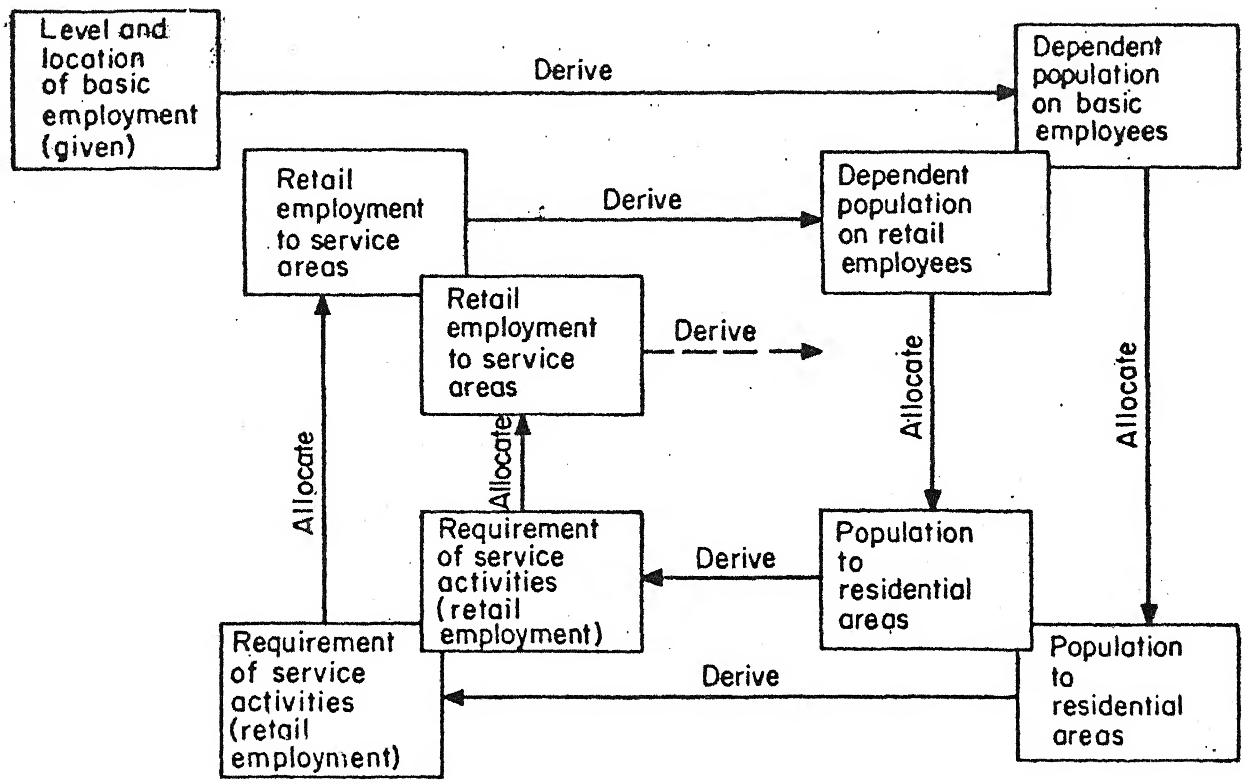


FIG. 1.1 Functional Structure of the Lowry Model

1.4 The Lowry Model

The Lowry model conceives urban activities in terms of three broad categories which are the basic, service and household. The main determinants of the location of residential population in the model are the level and distribution of basic employment, transport network and population constraints. The demands for service employment are distributed in relation to the population distribution. The model consists of two allocation submodels, of the gravity type which are usually labelled as the residential submodel and the service submodel. The equations are usually solved by an iterative technique to produce stable co-distribution of population and employment.

1.5 Basic Sector

This covers all industrial, business, and administrative establishments, whose clients are predominantly non local. These 'export' industries are relatively unconstrained in local site selection by problems of access to local market, and their employment levels are primarily dependent on events outside the local economy. Consequently, they have been treated as exogenous to the model, as activities whose locations and employment level must be assumed as "given".

1.6 Household Sector

Consisting of the residential population it is assumed that the level of employment in the retail sector depends directly on the number of resident households. The number of resident

households in turn depends upon the number of basic and retail jobs available at the given time. Further, it is assumed that residential site selection is powerfully influenced by the location of the resident's place of work.

1.7 Retail Sector:

This sector comprises of business, administrative and other establishment which deal predominantly and directly with the local residential population. Site selection is assumed to be powerfully constrained by problems of access to local residents and employment levels are assumed to be closely tied to local growth of population. The locations and levels of employment of establishments in this sector are treated as endogenous variables whose values are determined within the model.

1.8 Study frame work

The main objective of this project is to predict the spatial distribution of Kanpur using Lowry model. The model would also be able to predict what would be the scenario spatial distribution of Kanpur if some socio-economic parameters are changed.

The data used in this thesis work were from the data available at Centre for Transportation Engineering Management, I.I.T. Kanpur, for the Kanpur area transportation study. A detailed home survey was conducted which includes all type of information viz, income, mode of transport, purpose of journey destination etc. More than 15% of residence in each chak was

interviewed and the data collected was statistically tested before being used for the analysis.

1.9 Objectives of the Thesis

This thesis describes a landuse transport model that may be used to explore the activity, allocation and transport demand implications of a wide range of development concepts for Indian metropolitan areas. The model described in this thesis was developed and calibrated for Kanpur Municipal area. The specific objectives for the thesis are described below:

1. To develop a landuse transport model that is aggregated by socio-economic characteristics, purpose and mode group and which may be used in strategic planning studies for urban areas in India.
2. To calibrate the model for work and service trips on the basis of the data available in the Kanpur metropolitan area.
3. To demonstrate how the model may be used in planning studies of Kanpur urban region.
4. To demonstrate spatial distribution of activities brought about by the changes in parameters like increased number of mills, increased unemployment, better living index etc.
5. To determine the coefficients which are used in Lowry model to predict spatial allocation.
6. To develop a landuse transport model that may be used in strategic planning studies for cities in India.
7. To develop a tool that will assit urban planners in India in arriving at solutions if problems created by rapid

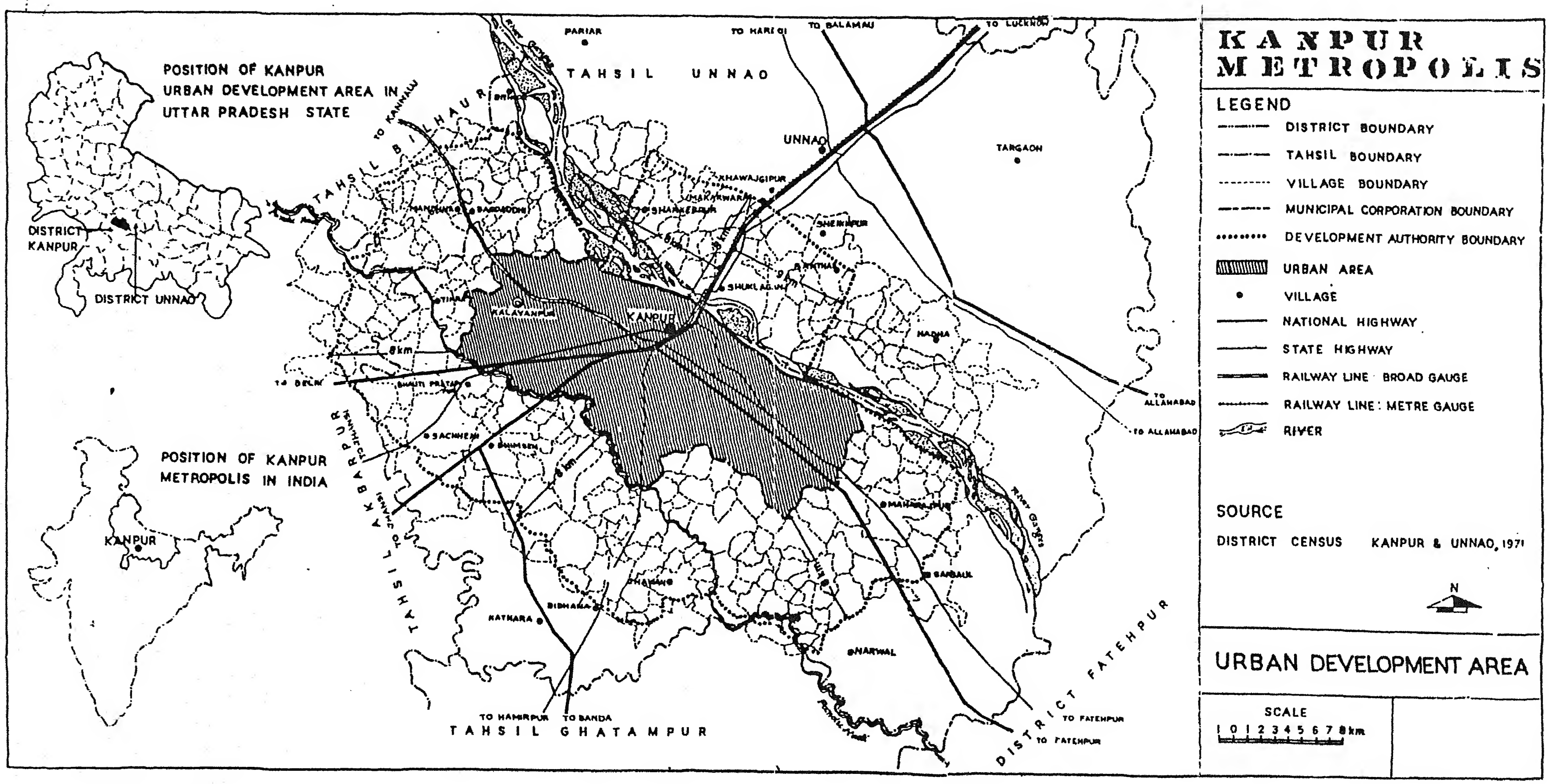


FIG. 1.2 Kanpur Metropolis

urbanization.

The purpose of the landuse models is to forecast land development for the zones of an urban area, taking into account in this process certain assumption about the influence of the transportation system in the determination of future pattern of location. It interesting to know how the model will predict when the data available are used to predict the spatial distribution at Kanpur.

1.10 Introduction of Kanpur Metropolis

1.10.1 General

Kanpur is not only the largest industrial city but also a metropolitan city. Kanpur founded on the banks of river Ganges as a military camp has gradually developed over the years into a premier urban centre because of its trading and industrial services to a vast hinterland with a population of nearly 1.7 million (as per 1981 census). It is the second largest metropolis of Northern India, after New Delhi and the largest city of U.P. It is eighth amongst the twelve metropolitan cities in the country.

1.10.2 Features of Kanpur

The total area of Kanpur Municipal Corporation, including the cantonment is nearly 300 Sq. km (KDA report). It has 50 wards and 221 chaks The importance of Kanpur city can be gauged by the fact that it contained nearly 42.5% of total population. Kanpur

can be counted among one of the largest industrial cities of India having a percentage of 37.9 of total working force as industrial workers. The spatial development of Kanpur has been linear. The development in east west direction is for a length of 27 km while the development in North-South direction is extended for only 12 km. The urban from of the city has been greatly influenced by the establishment of various types of industries from time to time. Primarily due to the physical constraint by river Ganges in the North and the cantonment in the east, the industrial growth has mainly followed a western expansion influencing the urban growth in a linear form from east to west.

Functionally the city presents four major landuse zones. The CBD lies to the eastern end of the corporation are surrounded by the cantonment in the east and the railway station and yards in the south. To the west of this zone, a major portion of the new developments have been for public and semi public landuse juxtaposed by congested older residential parts of the city. To the south-west of this zone also, a major portion of land has been used by sporadic industrial activities which also extend beyond the railway line in the south. Therefore, all major new residential developments have come up further south west of the CBD with the railway line pos ing physical barriers.

1.10.3 Connectivity of Kanpur

Major road connections between the metropolis and its hinterland are provided by the National Highway No.2 and 25. NH 2 connects Kanpur city with Calcutta, Allahabad and Varanasi. NH 25

extends from Lucknow and connects Kanpur with Pukhrayan, Bhoginpur, Kalpi and Jhansi on to Shivpuri in Madhya Pradesh. State Highway No. 22 (Grand Trunk Road) starts from Kanpur and provides connection to Kanauj, Fatehgarh, Etah and Aligarh. SH17 runs through the southern half of the metropolis and is the principal connecting road between the city and the two other district centers Banda and Hamirpur. Besides this MDR 55 popularly known as Bara-Akbarpur sikannadra Road is spur of the NH 25 and NH 2 starting about 25 km south west of Kanpur. MDR 72 also known as the Bhoginipur-Ghatampur-Bindki Road starts from south west of Kanpur as another spur of NH 25 and NH 2 . Kanpur is also linked by air to Lucknow, Calcutta, Delhi, Bombay and Ahmedabad.

All important neighbouring places are directly linked with Kanpur by means railways. Towns viz, Bindki, Pokhrayan, Hamirpur, Banda, Orai, Kalpi and Fatehpur are linked to Kanpur by broad gauge railway line. Farrukhabad, Kannauj and Kasganj are directly linked by metre gauge railway lines while Etawah, Bharthana and Jaswant Nagar are accessible by broad gauge railway route.

1.11 Thesis Organization

Including introducton there are five chapter in this report. Chapter two while briefly reviewing various transport models used, and compare the models between themselves. The subject matter of chapter three is on how to solve the Lowry model.

The chapter four describes how the calibration for works and service trip are being computed for the simulation of Lowry model. The interpretation and analysis of the results and observations are described in chapter five.

CHAPTER 2

LITERATURE SURVEY

2.1 General

Activities, housing and transportation are the three important components of a complex urban system. Activities are normally associated with the places of work, education, recreation, health centers etc. Housing are the places of residence. The interaction between the places of work and places of residence is brought about by the transportation facilities such as road, rail etc. Urban planners are concerned with the most appropriate arrangement of these subsystems to yield an integrated urban structure in the form of master plans. Nevertheless decisions regarding location and arrangement of the components are basically done through an understanding of the urban characteristics and experience of the concerned.

Over the past two decades many research workers have established that there are quantifiable relationships between activities, housing and transportation and that optimal arrangement are possible by minimizing transportation requirement. It is only recently that considerable interest is shown by land use and transportation planners for the application of quantification methods of land use transportation planning for urban development as against heuristic approaches [3].

Among the various approaches developed in this direction,

land use transportation models are the most popular versions. They attempt to minimise travel demands through manipulation of activity locations. A large number of computer based algorithms are now available for dealing simultaneously a large number of variables intrinsic to comprehensive preparation of urban structures.

2.2 Review of Models

A large number of land use models have been developed in the past decade and each model structure is influenced by the purpose for which the model is intended to serve. While reviewing land use models one should distinguish between operational models and those of basic research. Some of the major difference between operational and research models are as follows :

(i) Operational models are generally derived from simple logical structure and utilize routine variable collected by the planning and other agencies constructed with few variables, these models are sensitive to a limited number of development polices and emphasizes on stability.

(ii) Research models are generally derived from complex logical structure and utilize data collected by specially designed surveys. Constructed with many variables the models are sensitive to a large number of developmental related variables and emphasizes on sensitivity.

Table 2.1 below shows the various offshoots of the Lowry model.

Table 2.1

Operational Model	Research models
Emphasis on forecasting stability	Emphasis on forecasting sensitivity
Constructed with aggregated variable	Constructed with disaggregated variable.
Use few development control variables and sensitive to a limited number of development policies.	Sensitive to a large no. of development and other control variables.
Utilize variables collected routinely by planning and other govt. agencies.	Utilize frequently variables collected in special surveys.
Logical structure of model is usually quite simple	Logical structure of model is usually complex.

Many of the recent planning studies have stressed the need for operational type models with modest data requirements. Putman has classified land use models into the following four groups.

2.2.1 Lowry Derivative Models

This is a large group of models based on straight forward set relationship between place of work, place of residence and service places. Most of these models deal with both residential location and non basic employment. All these models require an exogeneously provided set of basic employment location estimates.

2.2.2 The Empiric Models

This is a somewhat smaller group of many applications of the same model. The model is a set of linear difference equations with no explicit theoretical structure. The model applications involve statistical analysis of an urban data base with the

specific variables used in each application being determined as a consequence of their results. The models include both residential location and location of all types of employment.

2.2.3 The Research Models

This set constitute a small assortment of models with potential for application at some future time, but currently in the developing stage. Examples of these are the revised Herbert Stevens model, the National Bureau of Economic Research (NBER) model and the Birch model.

2.2.4 A Miscellany of other Models

A group of models, proposed but not implemented, implemented but not successfully, implemented but too complex, or tailor made to a particular circumstance to allow application elsewhere.

Having grouped the models this way, Putman remarks that the last two groups were not appropriate for further investigation. After a thorough testing of the Lowry derivative models and Empiric models, Putman concludes that Empiric achieves good fit to base data, but it is not adequately sensitive to changes in input variables. This is probably due to its lack of an explicit theoretical form. The model has, however, been very useful for short term urban projections and it should be remembered that at first, even its authors claimed associative validity rather than any genuine theoretical validity. Whereas Lowry model derivatives did not fit the base data quite as well as Empiric, its response to changes in input variable was excellent. It

indicates that the model would give more accurate forecasts than Empiric, this is especially when the forecasts are of response to policy inputs.

Besides this group of models have the following advantages : -

(a) Limited data requirements

(b) Simplicity and adaptability

(c) Comprehensiveness and economy.

Besides these factors, Lowry model established its superiority over other models.

2.3 Lowry Derivative Models

Ever since the publication of the Lowry model, researchers in the field of urban and transportation engineering and planning have shown a lot of interest in this model. **Examination of the Lowry model reveals that there are different ways in which solutions to the model could be obtained and perhaps this flexibility is one of the main features of the model stimulating its further development.**

It is pointed out that the prime concern of the thesis is with operational type land use models.

2.3.1 Lowry Model

The model was developed by Ira S. Lowry in USA in 1962. The American-Yugoslav Project referred to as the Lyvbljana Project in Planning studies, involves an application of the original Lowry model. For a 123 zone system 3 policy inputs of

transport network, the pattern of industrial locations and the densities of land development are used to estimate the population and population serving employment distribution and the land consumed by these activities [15]. Population is allocated to each zone according to relative accessibility of each residential zone to employment. Land use accounts are kept and the population to be relocated is allocated to zones with available capacity.

2.9 Different models and its characteristics

Table 2·2 Lowry derivative landuse models.

S.No.	Model	Developed by	Remarks
1.	Lowry model	Lowry	Pittsburg Regional Plan, 1964
2.	TOMM-1 (Time Oriented Metropolitan Model)	Crecine	Further Development of Lowry Model 1965.
3.	BASS (Bay Area Simulation Study)	Goldner & Garybeal	Bay Area Study, 1965
4.	Garin Rogers Model	Garin-Rogers	Matrix Formulation of Lowry Model 1966
5.	TOMM-11	Crecine	Improvement of TOMM-1 1965
6.	PLUM (Projective Land Use Model)	Goldner	Modification of BASS Model 1968
7.	Wilson Model	Wilson	Entropy maximization and systematic handling of constraints
8.	Garin-Lowry Model variation	Cripps & Foot Batty Stubbs & Barber	Modification contain treatment of locational constraint, disaggregation and dynamic nature of the model application upto 1975

S.No.	Model	Developed by	Remarks
9.	IPLUM (Incremental Projective Land Use Model)	Putman	Modification of PLUM with Incremental Projections, 1971
10.	Hutchinson Model	Hutchinson	Landuse transportation stragies, 1975
11.	Disaggregated Land use Transport Model	Sarna	Disaggregated Landuse Transport Model for Delhi,India, 1975
12.	DRAM (Disaggregated Residential Allocation Model)	Putman	Disaggregated Residential Allocation Model, 1976
13.	Macket Model	Macket	Regional travel, dynamic,economic activities, disaggregation 1976
14.	ITPLUM (Interrelationship of Transportation Planning Land Use Model)	Putman	Inter relationship transport development and land development 1976

This chapter describes the various landuse model and its merits and demerits. Among them Lowry model is said to be the best model. So Lowry model is selected here to predict the spatial distribution of Kanpur metropolitan area using the available data. Next chapter deals with what is Lowry model and how to find the spatial distribution using Lowry model

CHAPTER 3

LOWRY MODEL

3.1 The Formal Model of Lowry

A close approximation to a general model of urban form is the Pittsburgh model. The model provides some details about the characteristics of landuse, population and economic activities that is allotted to various sub-areas. Though it is structurally well adapted to deal with incremental changes and the lag variables, it fails to provide a clear cut picture of change over time.

A solution to the model referred to an equilibrium solution provides the pattern of landuse and distribution of employment and population. This solution is obtained by solving a set of equation of which the model is built. The information required in the form of input to the model are the amounts and distribution of basic employment and basic land. It is on the basis of this input, that the model provides a solution giving details like appropriate amounts of retail employment and households among the sub-areas of metropolitan. The model simulates the behaviour of households and enterprises under circumstances, some of which are within their control and some outside their control. By varying the explicit parameters of the model it possible to conduct policy experiment.

In the following section, the formal logic of the model is given as a set of simultaneous equations.

Subsequently the computational steps used to solve the system is described.

3.2 The Model as a system of equations

The logical structure of the model can be expressed in nine simultaneous equations and three inequalities. These standard components are replicated many times in the complete system. The following notation will be used:

A = area of land (square kilometre)

E = employment (number of persons)

N = population (number of households)

T = index of trip distribution

Z = constraints

In conjunction with these symbols, the reader will find the following superscripts and subscripts:

U = unusable land

B = basic sector

R = retail sector

H = household sector

k = class of establishments within the retail sector; also defines related class of "shopping" trips

m = number of classes of retail establishments (k=1,...m)

i,j = sub-areas of a bounded region, called tracts or zones

n = number of tracts (i=1,...n; j=1,...n)

Unspecified functions and coefficients are represented by lower-case letters: a,b,c,d,e,f,g.

3.3 Landuse

We are given the area of each chak, and the amount of land therein which is not usable by any of the activities with which we are concerned. The remainder of the land in each chak is available for use by basic establishments, retail establishments, and households. All land not otherwise assigned is treated as available for residential use.

$$A_j = A^U{}_j + A^B{}_j + A^R{}_j + A^H{}_j \qquad (3.1)$$

3.4 Basic Sector

For each chak, we are given exogenously the quantity of land used by basic establishments ($A^B{}_j$) and the employment opportunities provided by these establishments ($E^B{}_j$).

3.5 Retail Sector

Retail establishments are divided into m groups, each of which has a characteristic production function; the elements of this production function which enter directly into the model are: minimum efficient size of establishments, number of clients required to support one employee, and number of square kilometre of space per employee. Since local consumer demand provides the market for establishments of this sector, we may treat employment in each line of retail trade as roughly a function of the number of households in the region:

$$E^k = a^k N \qquad (3.2)$$

The distribution of this retail employment among the square-kilometre chaks depends on the strength of the market at

each location. Assuming that shopping trips originate either from homes or from workplaces, the market potential of any given location can be defined as a weighted index of the number of households in the surrounding areas, and the number of persons employed nearby.

$$E^k{}_j = b^k \left[\sum_{i=1}^{n} \left(\frac{c^k N_i}{T^k_{ij}} \right) + d^k E_j \right] \quad (3.3)$$

This equation could easily be made more general; however, we have assumed that none but short-range pedestrian trips originate from workplaces, so that the only relevant origins are those in chak j. Those originating from home are often longer vehicular trips, but the likelihood of a shopping trip from i to j diminishes with intervening distance. (The variable T^k_{ij} is a positive function of this distance, fitted from an analysis of home-based vehicular shopping trips). The coefficients c^k and d^k measure the relative importance of homes and workplaces as origins for a particular type of shopping. Finally, b^k is a scale factor which adjusts the retail employment in each chak to the regional total determined in Equation 3.2.

$$E^k = \sum_{j=1}^{n} E^k{}_j \quad (3.4)$$

In this way we determine the amount of employment in any chak for each line of retail trade. The sum of these employment figures, plus the quantity of basic employment allocated to the chak is total employment for that chak.

$$E_j = E^B{}_j + \sum_{k=1}^{m} E^k{}_j \quad (3.5)$$

Finally, with the aid of exogenously determined employment density coefficients (e^k) for each line of trade, we can determine the amount of land in each chak which will be occupied by retail establishments

$$A^R_j = \sum_{j=1}^{n} e^k E^k_j \qquad (3.6)$$

3.6 Household Sector

The region's population of households may be regarded as a function of total employment.

$$N = f \sum_{j=1}^{n} E_j \qquad (3.7)$$

The number of households in each chak is a function of that chak's accessibility to employment opportunities.

$$N_j = g \sum_{i=1}^{n} \frac{E_i}{T_{ij}} \qquad (3.8)$$

The coefficient g is a scale factor whose value is determined by the requirement that the sum of chak populations must equal the total population of the region as determined in Equation 3.7.

$$N = \sum_{j=1}^{n} N_j \qquad (3.9)$$

3.7 Constraints

In order to limit the dispersion of retail employment, we impose a minimum-size constraint (Z^k), expressed in terms of employment. If the market potential of a particular location

does not justify an establishment above this minimum size, the "customers" are sent elsewhere.

$$E_j^k \geq Z^k \quad \text{or else } E_j^k = 0 \qquad (3.10)$$

In order to prevent the system from generating excessive population densities in locations with high accessibility indices, we impose a maximum-density constraint (Z_j^H). The value of this constraint (number of households permitted per one square kilometre of residential space) may vary from chak to chak, as would be the case under zoning ordinances.

$$N_j \leq Z_j^H A_j^H \qquad (3.11)$$

Finally, the amount of land set aside for retail establishments by Equation 3.5 must not exceed the amount available.

$$A_j^R \leq A_j - A_j^U - A_j^B \qquad (3.12)$$

Taken together with the accounting relationships expressed in Equation 3.1, this constraint also prevents the assignment of negative values to residential land.

3.8 Solution of the System

Ignoring for the moment the three inequalities, one can show that the nine structural equations form an adequately-determined system, whose solution (if it exists) describes an "equilibrium" distribution of residential population. The formal adequacy of

this structure is demonstrated below by a count of equations and unknowns in the expanded system.

The model contains the following unknowns as shown in table 3.2.

Altogether, the expanded system contains $(m+1)n^2 + 8n + mn + 6m + 3$ unknowns. However, values are obtained exogenously for all but $4n + mn + 2m + 2$ of these unknowns. We may compare this remainder to a count of independent equations :

Equation Number	Number of times it appears in the expanded system
3.1	n
3.2	m
3.3	mn
3.4	m
3.5	n
3.6	n
3.7	1
3.8	n
3.9	1

We thus have a total of $4n + mn + 2m + 2$ independent equations, equal to the number of endogenous unknowns, a necessary but not sufficient condition of solution.

The addition of three inequalities as constraints on this system changes the problem considerably. Although it is possible that there may be simultaneous solutions in which none of the

Type	Symbol	Number in expanded system	Number exogenously determined
3.8.1 Variables			
Land	A_j	n	n
	$A^U{}_j$	n	n
	$A^B{}_j$	n	n
	$A^R{}_j$	n	-
	$A^H{}_j$	n	-
Employment	E_j	n	-
	$E^B{}_j$	n	n
	$E^k{}_j$	mn	-
	E^k	m	-
Population	N_j	n	-
	N	1 (one)	-
Trip-distribution indices	T_{ij}	n^2	n^2
	$T^k{}_{ij}$	mn^2	mn^2
3.8.2 Structural Parameters			
Retail employment coefficient *	a^k	m	m
Retail employment scale factor	b^k	m	-
Shopping trip weight factor	c^k, d^k	2m	2m
Retail employment density ratio	e^k	m	m
Labour force participation rate **	f	1 (one)	1 (one)
Population scale factor	g	1 (one)	-

* Retail employment per household
** In reciprocal form, 1/number of employed persons per household.

Table 3.2 Variables and Parameters used in Lowry Model

three constraints is binding for any chak, such good fortune cannot be expected. We need, therefore, a solution method which will allow us to apply these constraints where necessary, yet retain the "regular" solution values offered for most of the chak. Furthermore, this method (or at least its consequences) should preferably have some interpretation as an analogue to real-world events.

One such method of solution is described below.

3.8.3 Input data

The following data are given as an input to the model. The level, categorization and allocation of the basic employment. An inventory of land, classified as usable, basic or residential.The inter zonal network, from the network, distances are calibrated and used to determine the trip distribution indices.

3.8.3.1 Structural parameters retail employment coefficient, weight factors, retail employment density ratios, labour forces participation rate etc.

3.8.3.2 Constraints on densities of residential development, on the minimum size of a "cluster" of retail activities; and on the amount of land available in each zone.

3.8.4 Step One

The technique best adapted to machine computation is iterative method, beginning with Equation 3.1, 3.7, 3.8, and 3.9. As a first approximation, we assign the exogenously-determined value of E_i^B to the variable E_i (or E_j), and set $A_j^R = Ø$. These four

equations can then be partitioned from the rest of the system and solved for g, N_j, and N by an inner iteration. First we obtain a value for A^H_j from Equation 3.1.

$$A_j^H = A_j - A_j^U - A_j^B - A_j^R$$

The value of N is then established in Equation 3.7.

$$N = f \sum_{j=1}^{n} E_j$$

Or, in order to speed convergence, we can anticipate the final value of N by allowing for the labor-force requirements of retail establishments as well; where E^B represents all basic employment,

We then compute population potentials.

$$\overset{1}{N_j} = \sum_{i=1}^{n} \frac{E_i}{T_{ij}}$$

The value of the scale factor (g) is determined by reference to the total population to be allocated, as follows:

$$\overset{1}{g} = \frac{N}{\sum_{j=1}^{n} \overset{1}{N_j}}$$

This scale factor is used to reduce the population potentials to a second approximation.

$$\overset{2}{N_j} = \overset{1}{g}\,\overset{1}{N_j}$$

The left hand term is then tested against the maximum density constraint $(\overset{H}{Z_j})$ for all cases in which

$$\overset{2}{N_j} \geq \overset{H}{Z_j}\,\overset{H}{A_j}\ ,$$

we set $\overset{3}{N_j} = \overset{H}{Z_j}\overset{H}{A_j}$

The excess population of tract j (i.e., $\overset{2}{N_j} - \overset{3}{N_j}$) is distributed among all other tracts in proportion to their population potentials by revising the scale factor once more.

For all other cases, $\overset{3}{N_j} = \overset{2}{g}\,\overset{2}{N_j}$, and we close the system with :

$$N = \sum_{j=1}^{n} \overset{3}{N_j}$$

3.8.5 Step Two

We can now partition Equation 3.2, 3.3, and 3.4, and again solve by repeated approximations. The solution of the step One gives us values for N and N_j , which are now fed into Equation 3.2 and 3.3, respectively. Once more we use the exogenous E_j^B as a first approximation for E_j in Equation 3.3. We are then prepared to calculate employment potentials in retail trade k for each chak.

$$\overset{1}{E^k_j} = \sum_{i=1}^{n} \left(\frac{c^k N_i}{T^k_{ij}} \right) + d^k E_j$$

These potentials are rescaled so that they sum to the total employment determined from Equation 3.2.

$$E^k = a^k N$$

$$\overset{2}{E}{}^k_j = b^k \overset{1}{E}{}^k_j$$

where $$b^k = \frac{E^k}{\sum_{j=1}^{n} \overset{1}{E}{}^k_j}$$

This provisional solution is then tested against the minimum-size constraint. We use a search routine to locate the smallest $\overset{2}{E}{}^k_j$, set it equal to zero and rescale (increase) employment in all other chaks. This process is repeated until there are no instances in which $\overset{2}{E}{}^k_j$ is less than Z^k, and Equation 3.4 is satisfied.

$$E^k = \sum_{j=1}^{n} E_j{}^k$$

3.8.6 Step Three

When the second step has been completed for each of the m retail trades, Equations 3.5 and 3.6 may be solved by substitution. The retail-land variable ($A_j{}^R$) generated by Equation 3.6 is then tested against the amount of space actually available in each chak; i.e., where $A^R{}_j > A_j - A^U{}_j - A^B{}_j$, we set $A^R{}_j = A_j - A^U{}_j - A^B{}_j$. In other words, if there is not enough space to accommodate retail employment at average densities, we

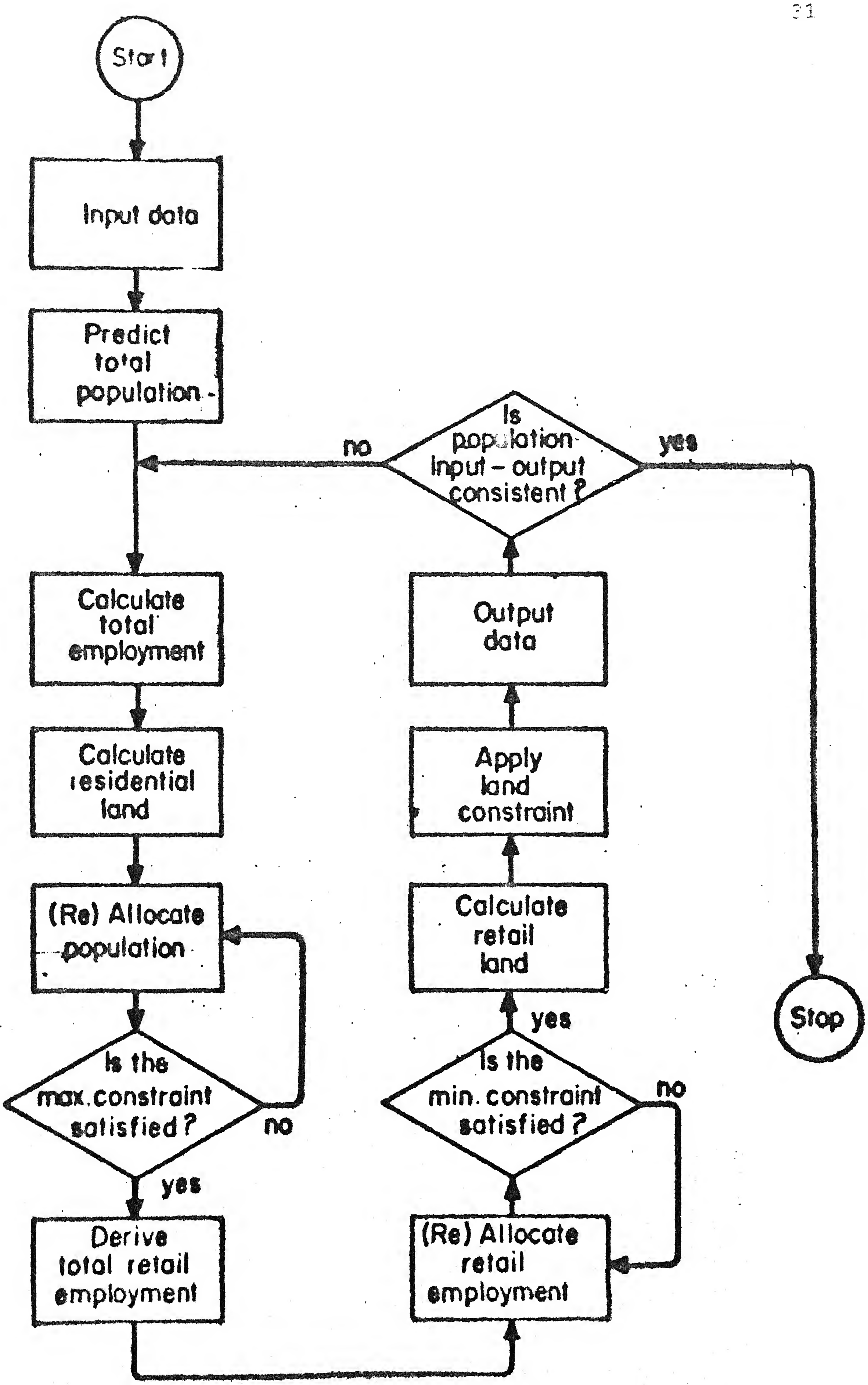


FIG. 3.1 Formulation of Lowry's Model

allow overcrowding. Note that retail uses still have priority over residential uses; if population has been allocated to such a chak by Step One, it will be removed by the residential-density constraint on the next grand loop.

The values of E_j yielded by Equation 3.5 will be equal to or greater than the assumed E_j used in the first trial of Equation 3.8, and the same is true of the values of $A^R{}_j$ yielded by Equation 3.6. Our solution method thus slowly feeds in retail employment and land use as determinants of population distribution. We may now return with these new values E_j and $A^R{}_j$ to the system composed of Equations 3.1, 3.7, 3.8, and 3.9, beginning a second iteration of the entire model. We continue in this fashion until the iterations converge on a stable set of values for all the variables. Refer Fig 3.1

3.9 Some features of the iterative solution

During successive iterations, retail employment and landuse are fed into the model. The presence of retail employment of that zone and surrounding zone; the land available for residential use is reduced because of additional land absorbed by retail establishment. Thus the above factors have a forceful impact on population density. The maximum density constraint is brought into picture some times by the above said events. In such cases there is a high probability that the system will never stabilize since there has to be a non-homogeneous redistribution of population among zones.

If there are minimum size constraints, they are also brought

into picture sometimes. Its implication is that as population shifts a zone which was previously below the minimum market potential crosses the boundary; the zone is to recover patronage distributed earlier elsewhere.

In experimental runs, however, it have found that such shifts in population and retail employment do not ordinarily disturb the system enough to prevent convergence. Since these variables are distance-weighted geographical averages of other variables, the impact of a local change tends, in turn, to be localized.

Even though these shifts do not prevent convergence on a set of solution values, it is fairly clear from the nature of our constraints that the set may not be unique. If the same data were fed into the program in a different sequence, it is conceivable that a somewhat different distribution of retail employment and of population would be generated by the program without violating the system of equations into which the solution values must fit.

Such a formally indeterminate system may still have a unique meaningful solution, provided we can give a dynamic interpretation to the system which enables us to rationalize the order in which data are fed into the computational sequence.

CHAPTER 4

CALIBRATION

4.1 General

Calibration is the process of finding a set of numerical parameter, for a specific equation (or a set of equations) which produce the best fit of those equations to a given data set. In a particular example of a given data set and a set of equations, any procedure for adjusting parameters to fit the equation to the data may properly be called calibration procedure. The variation between the actual data set and predicted values is represented by various statistical parameters and this is called the goodness of fit.

All the 133 chaks have been combined to make 7 zones for the purposes of finding the parameters. The chaks coming under each zone is assumed to have similar characteristics. The zones are made in such a way that the area, population, service characters are almost equal.

The zone four can be considered as the Central Business District. The data has been collected from chak 1 to 133. Refer figure 4.1 to get more ideas about the location of the zones. [7].

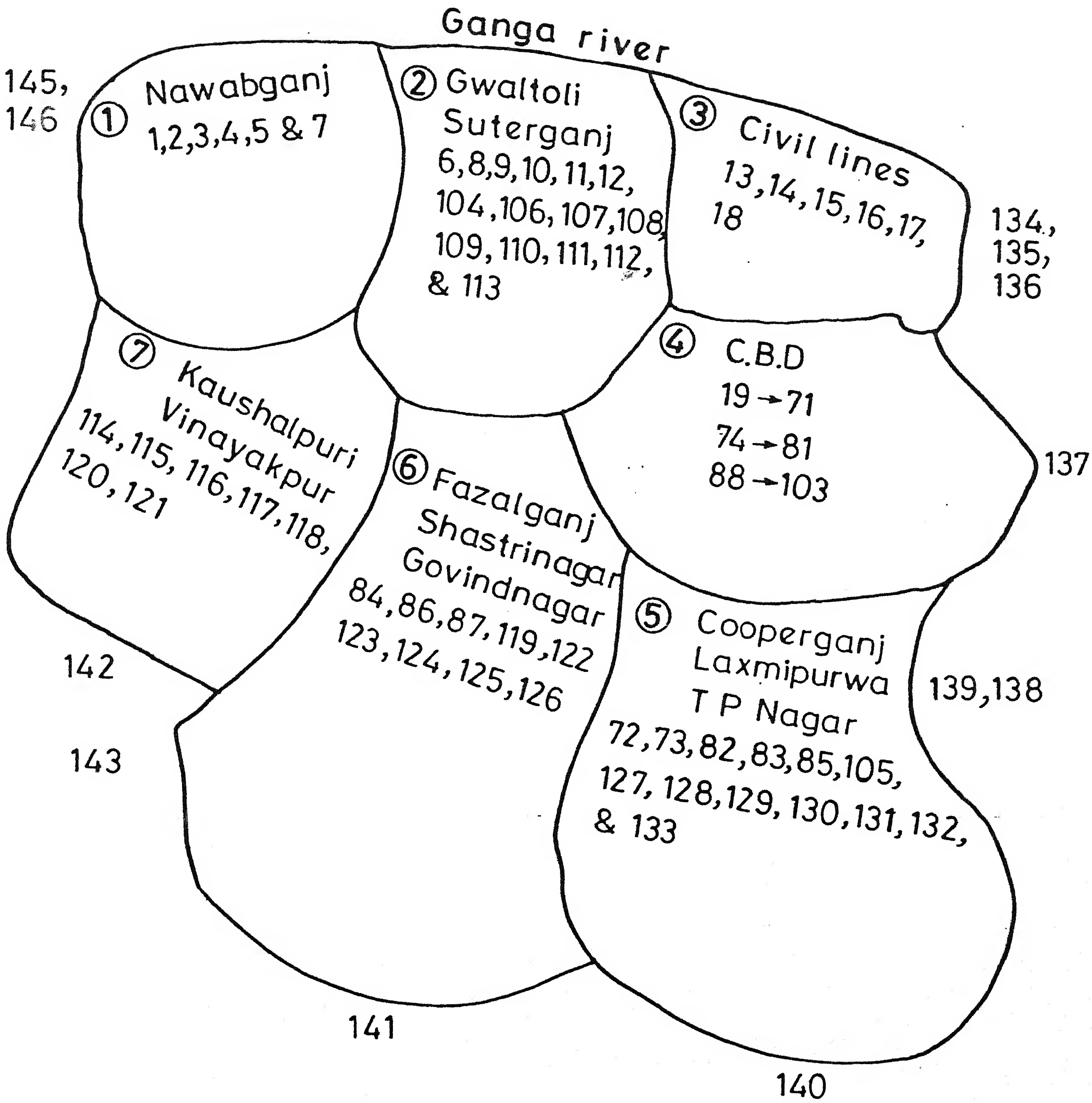


FIG. 4.1 Location of Zones

Kanpur metropolis consists of 221 chaks which are aggregated into 50 wards. To get the spatial distribution of Kanpur metropolis using the Lowry model, the area is divided into 146 parts in which 1 to 133 are chakwise and remaining by zonewise. Area, name, basic employment and density of households of each chak or zone are given in table 4.2

Table Number 4.1

Zone No.	chak numbers	Total No. of chaks
1	1 to 5,7	6
2	6,8 to 12, 104, 106 to 113	15
3	13 to 18	6
4	19 to 71 74 to 81 88 to 103	77
5	72,73,82,83,85,105 127 to 130	13
6	84,86,87,119,122 to 126	9
7	114 to 118, 120, 121	7

Table 4·2 Kanpur metropolis

Chak or Zone Number	Name	Area in Sq.Km	Unusable land in Sq.m.	Basic employment	Density of household
1.	Nawabganj	4.250	879000	479	3000
2.	Nawabganj	0.600	0.0	1126	6000
3.	Azad Nagar	0.650	70000	175	6000
4.	Old Kanpur	0.250	0.0	0	6000
5.	Old Kanpur	0.170	20000	211	6000
6.	Bhairon Ghat	0.450	0.0	5940	3000
7.	Benajhabar	1.390	55000	1298	3000
8.	Arya Nagar	0.810	0.0	69	6000
9.	McRobert Ganj	0.510	70000	135	6000
10.	Khalasi Line	0.650	0.0	0	6000
11.	Sutarganj	0.330	0.0	0	12000
12.	Gwaltoli	0.350	0.0	75	12000
13.	Parmath	0.300	10000	800	9000
14.	Civil Lines	1.050	0.0	17609	6000
15.	Civil Lines	0.460	109000	4742	6000
16.	Civil Lines	1.220	189000	2505	3000
17.	Kursavan	0.150	0.0	20	8500
18.	Kursavan	0.130	0.0	0	9000
19.	Patkapur	0.120	0.0	83	12000
20.	Chatai Mohal	0.120	0.0	0	12000
21.	Chatai Mohal	0.120	0.0	0	6000
22.	Pheelkhana	0.120	0.0	0	6500
23.	Patkapur	0.110	0.0	0	6000
24.	Patkapur	0.120	0.0	741	12000
25.	Karachikhana	0.150	0.0	150	3000
26.	Roti Godam	0.110	0.0	86	3000
27.	Roti Godam	0.110	0.0	0	9000
28.	Pheelkhana	0.150	0.0	0	9000
29.	Veldari Mohal	0.140	0.0	0	6000
30.	Maheswari Mohal	0.110	0.0	0	12000
31.	Lathi Mohal	0.340	0.0	0	10000
32.	Old Subjimandi	0.110	0.0	0	15000
33.	Chowk Thathari	0.115	0.0	0	15000
34.	Hata Sawai Singh	0.110	0.0	0	6000
35.	Bengali Mohal	0.150	0.0	0	12000
36.	Mengali Mohal	0.110	0.0	0	9000
37.	Mall Road	0.170	0.0	1450	8000
38.	Narial bazar	0.120	0.0	17	12000
39.	Maida bazar	0.130	0.0	0	3000
40.	Nayachowk	0.140	0.0	277	12000
41.	Farrashkhana	0.120	0.0	0	6000
42.	Bisati bazar	0.140	0.0	75	8000
43.	Chowksarafa	0.110	0.0	150	15000
44.	Boocharkhana	0.130	0.0	0	15000
45.	Moolganj	0.110	0.0	0	9000
46.	Chhapra Mohal	0.130	0.0	0	9000
47.	Hatiya	0.130	0.0	0	6000
48.	Generalganj	0.110	0.0	0	15000
49.	Generalganj	0.240	0.0	92	6000

50.	Nayaganj	0.130	0.0	0	15000
51.	Ramganj	0.110	0.0	130	6000
52.	Nayaganj	0.130	0.0	80	5000
53.	Nayaganj	0.130	0.0	0	5000
54.	Nayaganj	0.130	0.0	0	5000
55.	Nayaganj	0.110	0.0	0	8000
56.	Shatranji Mohal	0.110	0.0	0	9000
57.	Sirki Mohal	0.110	0.0	0	9000
58.	Naachghar	0.120	0.0	80	9000
59.	Naachghar	0.110	0.0	0	12000
60.	Dalmandi	0.170	0.0	0	5000
61.	Seetaram Mohal	0.120	0.0	30	12000
62.	Harbans Mohal	0.130	0.0	0	12000
63.	Harbans Mohal	0.170	0.0	0	6000
64.	Gararia Mohal	0.130	0.0	0	15000
65.	Moti Mohal	0.130	0.0	0	12000
66.	Kachhiana Mohal	0.130	0.0	0	15000
67.	Daulatganj	0.110	0.0	0	8000
68.	Lokman Mohal	0.120	0.0	0	9000
69.	Daanakhori	0.140	0.0	0	12000
70.	Mathuri Mohal	0.120	0.0	0	6000
71.	Sutarkhana	0.250	0.0	0	12000
72.	Sutarkhana	0.180	50000	6500	3000
73.	Collectorganj	0.370	0.0	0	3000
74.	Dhankutti	0.180	0.0	0	9000
75.	Ranjeet Purwa	0.150	0.0	10	8000
76.	Coolie bazar	0.250	0.0	0	15000
77.	Coolie bazar	0.140	0.0	0	10000
78.	Anwarganj	0.160	0.0	0	12000
79.	Bansmandi	0.120	0.0	23	9000
80.	Cooperganj	0.120	0.0	28	9000
81.	Cooperganj	0.180	0.0	425	9000
82.	Cooperganj railway colony	0.340	0.0	205	3000
83.	Juhikhurd	1.440	154000	6353	3000
84.	Zareeb Chouki	2.150	40000	3287	3000
85.	Laxmipurwa	0.540	0.0	8148	6000
86.	Raipurwa	0.250	0.0	25	18000
87.	Bhannanapurwa	0.370	0.0	107	6000
88.	Chamanganj	0.350	0.0	461	15000
89.	Dalalpurwa	0.200	0.0	74	15000
90.	Anwarganj	0.110	0.0	4795	12000
91.	Dalalpurwa	0.160	0.0	0	6000
92.	Heeramanpurwa	0.260	0.0	0	9000
93.	Boocherkhana	0.260	0.0	0	9000
94.	Farrashkhana	0.130	0.0	0	6000
95.	Farrashkhana	0.130	0.0	30	9000
96.	Colonelganj	0.190	0.0	835	9000
97.	Talak Mohal	0.170	0.0	0	9000
98.	Bekanganj	0.110	38000	0	9000
99.	Bekanganj	0.140	0.0	0	15000
100.	Colonelganj	0.160	0.0	0	21000
101.	Colonelganj	0.230	0.0	70	2400
102.	Colonelganj	0.170	0.0	80	6000
103.	Colonelganj	0.210	0.0	0	15000

104.	Sisamau	0.430	0.0	150	10000
105.	Chamanganj	0.470	0.0	328	15000
106.	Gandhi Nagar	0.170	0.0	99	21000
107.	Jawahar Nagar	0.130	0.0	0	30000
108.	Gandhi Nagar	0.110	0.0	0	15000
109.	Gandhi Nagar	0.120	0.0	150	30000
110.	Ramkrishna Nagar	0.140	0.0	162	12000
111.	Ashok Nagar	0.420	0.0	1124	9000
112.	Swaroop Nagar	0.600	30000	75	6000
113.	Swaroop Nagar	0.760	120000	759	3000
114.	Vinayakpur	2.980	74000	1855	3000
115.	Maswanpur	1.510	240000	0	3000
116.	Kailash Nagar	1.770	102000	0	3000
117.	Kakadeo	2.310	0.0	1526	3000
118.	Kaushalpuri	0.420	0.0	58	12000
119.	Krishna Nagar	0.440	20000	909	18000
120.	Kaushalpuri	0.790	0.0	465	3000
121.	Harihar Nath Sastri Nagar	0.810	0.0	4265	6000
122.	Sastri Nagar	0.890	43000	329	9000
123.	Fazalganj	1.430	238000	24398	5000
124.	Govind Nagar	1.450	357000	111	6000
125.	Govind Nagar	0.510	0.0	234	9000
126.	Govind Nagar	0.500	0.0	0	6000
127.	Juhi Hameerpur Road	0.700	0.0	11944	18000
128.	Kidwai Nagar	2.700	0.0	217	3000
129.	Babupurwa	0.950	0.0	0	6000
130.	Bagahi	0.160	0.0	80	30000
131.	Babupurwa	0.280	0.0	0	10000
132.	Babupurwa	0.350	0.0	30	15000
133.	Transport Nagar	1.690	278000	148	6000
134.	Railway Colony	18.560	1220000	19000	1400
135.	Jajmau	9.600	320000	4000	1400
136.	Harjender Nagar	7.680	0.0	5000	1400
137.	Chakeri	64.960	2640000	5000	1400
138.	Sanigawan	25.600	1280000	2000	1400
139.	COD	3.840	0.0	3513	1400
140.	Naubasta	26.050	0.0	6000	1400
141.	Nirala Nagar	14.720	400000	4000	1400
142.	Armapur	14.400	140000	4000	1400
143.	Panki	21.760	400000	1500	1400
144.	Kalpi	19.200	180000	4250	1400
145.	Kalyanpur	11.520	400000	3000	1400
146.	Bisayakpur	7.110	400000	2000	1400

4.2 Work Trip Calibration

From the statistical analysis of the data, it has been found that the empirical distribution of work trips by distance from residence may be fitted rather well with a negative power

function.

$$dp/dr = ar^{-x}$$

where a and x are parameters to be calibrated and 'r' is the distance from residence to work place. dp/dr is the distance derivative of trips. with distance.

Work trip producing from each chak to different destination, irrespective of mode is first computed. The shortest distance between chaks to chaks are known. Then a trip distribution table based on distance at a range of Ø.5Ø km is made. This will be known as 'observed' frequency of trip for work. A trip distribution function for work trip will be calibrated by IMSL routine.

In this work four types of negative power function are used. By using IMSL routines available in the DEC 1Ø9Ø Computer [A modified LENVEN BERG-MARGVARDT Algorithm] for finding the minimum of the sum of squares of m functions of n variables.

(1) $dp/dx = r^{-x}$

(2) $dp/dr = ar^{-x}$

(3) $dp/dr = (ar^2 - br + c)^{-1}$

(4) $dp/dr = ae^{-rx}$

Various allocation functions used by different authors who worked on the family of Lowry model are given in the table 4.3.

4.3 Allocation function

S.No.	Author	Function	Parameter value	Remarks
1.	Lowry	$d_{ij}^{-\alpha}$	$\alpha = 1.33$	d_{ij} = distance between centroids
2.	Garin	$d_{ij}^{-\alpha}$	$\alpha = 2$	d_{ij} = travel time between zone centroids
3.	Batty	$d_{ij}^{-\alpha}$ $d_{ij}^{-\beta}$	$\alpha = 2.4$ $\beta = 1.7$	d_{ij} = Average time distance between zone centroids
4.	Batty	$\exp-(\beta c_{ij})$ $\exp-(\alpha c_{ij})$	$\beta = 0.23$, $\alpha = 0.16$	c_{ij} = Generalized cost travel between zone centroids
5.	Hutchinson	$\exp(-\alpha d_{ij})$ $\exp(-\beta d_{ij})$	$\alpha = 0.124$, $\beta = 0.288$	d_{ij} = travel time between zones
6.	Sarna	$\exp(-\alpha d_{ij})$ $\exp(-\beta d_{ij})$	$\alpha = 0.105$ to 0.120, $\beta = 0.140$ to 0.120,	considered 3 income groups Low, middle, high d_{ij} = travel time between zones
7.	Putman	d_{ij}^{α} $\exp^{-\beta d_{ij}}$	α / β: 0.92 / 2.14 2.24 / 1.36 2.84 / 1.22 2.48 / 1.52	considered 4 income group

The parameters of the negative power function are found to be as follows:

1 $\quad dp/dr = 20.8\ e^{-0.377r}$ (Table 4.4, Fig 4.2) $R^2 = 0.9836$

2 $\quad dp/dr = 14.87\ r^{-0.825}$ (Table 4.4, Fig 4.3) $R^2 = 0.8444$

3 $\quad dp/dr = (0.02235r^2 - 0.6098r + 0.01015)^{-1}$ $R^2 = 0.8409$
(Table 4.4, Fig 4.4)

4.4 Service Trip Coefficient Calibration

The distribution of trip terminals for each type of service

Table 4.4 Observed vs predicted frequency of trip for work

Dist r in Km	Observed	Predicted 'pr1'	Predicted 'pr2'	Predicted 'pr3'
0.500	18.515	17.224	26.342	18.062
1.000	14.008	14.250	14.870	16.918
1.500	10.688	11.807	10.642	15.093
2.000	8.494	9.775	8.390	14.017
2.500	7.714	8.098	6.982	11.277
3.000	5.994	6.700	6.007	8.358
3.500	6.414	5.541	5.290	6.181
4.000	6.440	4.593	4.740	4.649
4.500	3.568	3.802	4.294	3.575
5.000	3.387	3.148	3.643	2.814
5.500	3.175	2.608	3.390	2.252
6.000	2.546	2.158	3.390	1.851
6.500	1.739	1.785	3.170	1.540
7.000	1.608	1.479	2.940	1.299
7.500	0.883	1.224	2.820	1.109
8.000	1.107	1.014	2.430	0.957
8.500	0.807	0.889	2.670	0.834
9.000	0.449	0.695	2.320	0.733
9.500	0.626	0.575	2.220	0.649
10.000	0.648	0.475	2.130	0.579
10.500	0.195	0.394	2.060	0.519
11.000	0.315	0.326	1.980	0.468
11.500	0.221	0.270	1.850	0.424
12.000	0.151	0.223	1.790	0.380
12.500	0.091	0.185	1.730	0.353
13.000	0.059	0.153	1.680	0.324
13.500	0.064	0.127	1.637	0.298
14.000	0.050	0.105	1.590	0.275
14.500	0.034	0.087	1.550	0.255
15.000	0.003	0.072	1.510	0.220
15.500	0.003	0.059	1.509	0.206
16.000	0.003	0.049	1.500	0.203

$$pr1 = 20.8\, e^{-0.377r}$$

$$pr2 = 14.87 r^{-0.825}$$

$$pr3 = (0.02235r^2 - 0.6098r + 0.01015)^{-1}$$

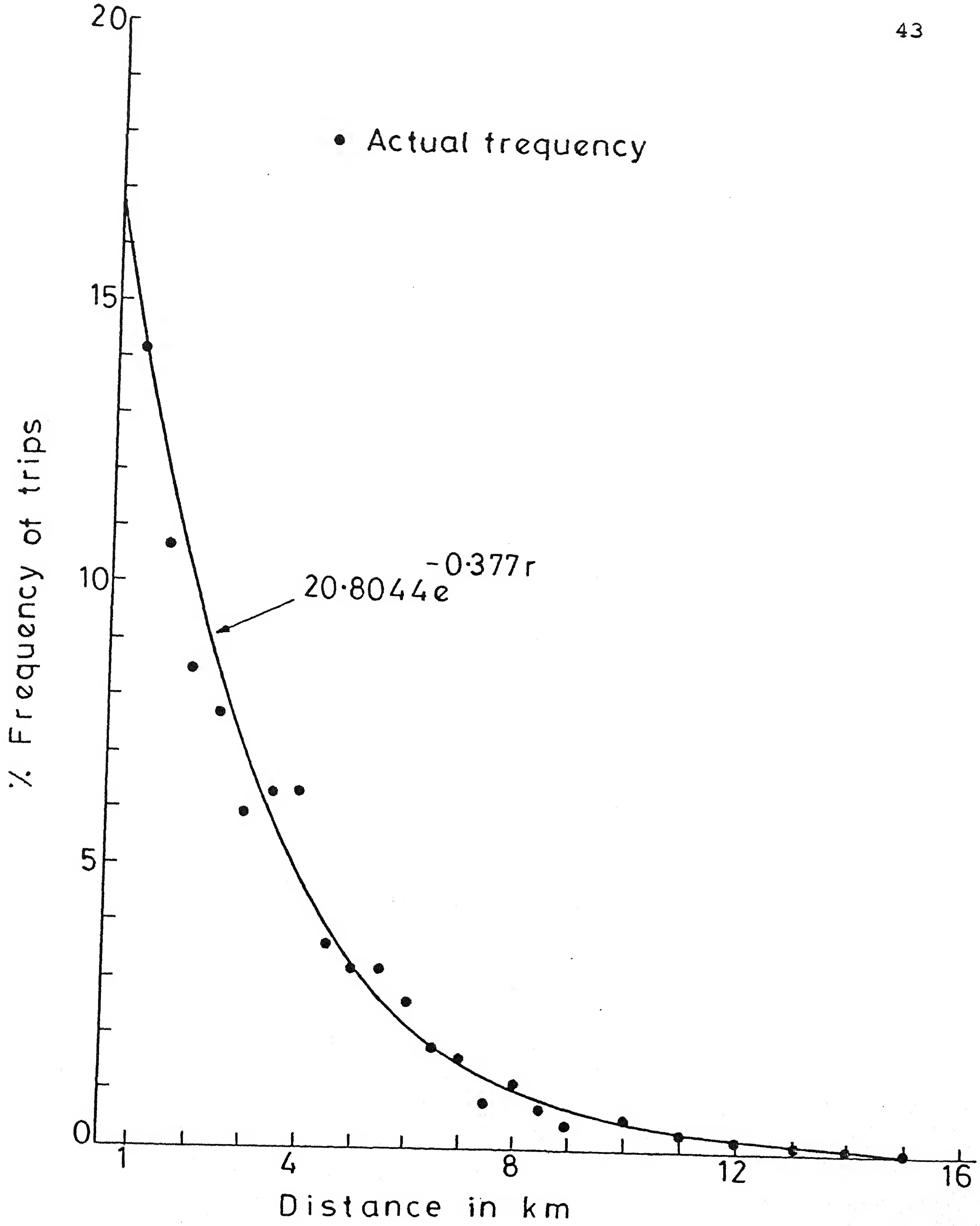


FIG. 4.2 Work Trip Calibration

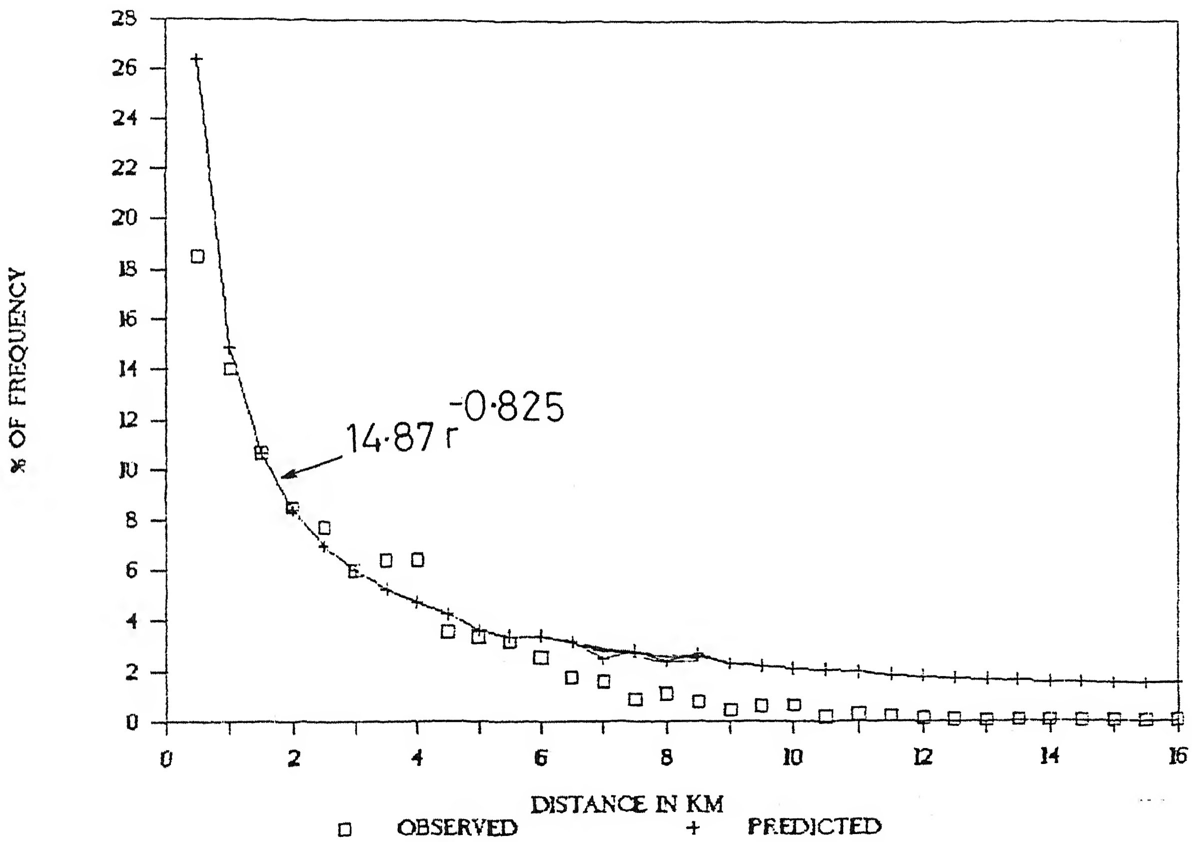


FIG. 4.3 Work Trip Calibration

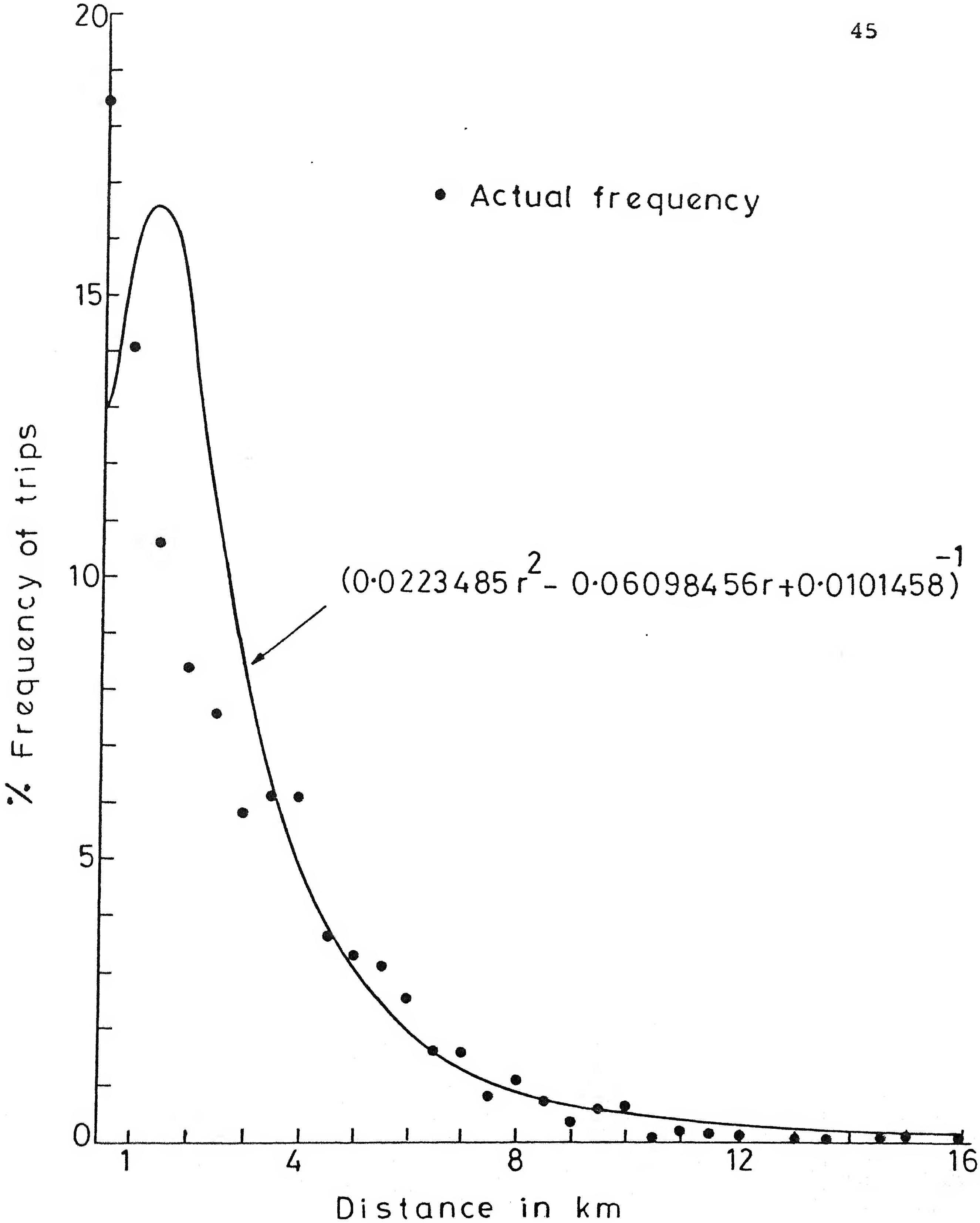


FIG. 4.4 Work Trip Calibration

trip originating in each of the zone was standardized, by adjusting for variations in the frequency of terminal opportunities. Since only a small number of trip records from any one residential area pertained to a particular type of shopping trip, the trip distribution indices, specific both as to residential area and to type of trip, were expectably unstable. When the index values for a specific trip of trip are weighted and averaged over all 7 zones, indices similar in nature to that for the work trips, can be plotted as functions of distance. The sequence of index values is not usually as regular as those found for work trips, and they could not be fit either with power or exponential functions. The best approximations were found to be reciprocal of quadratic function

$$dp/dr = (ar^2 - br+c)^{-1}$$

Supplementing the indices for home based shopping trips is an index for work based shopping trips, so that the market potential of a particular chak is affected by work place within the chak. For neighbourhood clusters, market potential contributed by residents is weighted by Ø.9Ø and that contributed by local employment by Ø.1Ø and for local clusters the weights are Ø.7Ø and Ø.3Ø respectively; and for the metropolitan clusters, the weights are Ø.5Ø and Ø.5Ø respectively.

4.5 Determination of Service Employment Coefficient

4.5.1 Neighbourhood cluster

It is assumed that the trip produced inside a chak or zone

Table 4.5 Observed vs predicted frequency of trips for neighbourhood cluster.

ZONE 1			ZONE 2		
Dist r in Km	Observd	Predictd 'pr1'	Dist r in Km	Observd	Predictd 'pr2'
0.200	4.000	5.915	0.150	7.250	9.827
0.300	19.000	16.505	0.200	16.150	12.091
0.500	58.000	62.418	0.250	8.490	15.022
0.600	15.000	12.514	0.300	6.280	18.744
0.750	3.000	3.528	0.350	29.240	23.231
			0.400	24.300	28.045
			0.900	8.220	8.118

$$pr1 = (2.8722420r^2 - 2.520618r - 0.558269)^{-1}$$

$$pr2 = (0.5830873r^2 - 0.585078r + 0.176393)^{-1}$$

ZONE 3			ZONE 4		
Dist r in Km	Observd	Predictd 'pr3'	Dist r in Km	Observd	Predictd 'pr4'
0.100	0.710	3.051	0.100	37.420	38.357
0.200	1.210	6.455	0.150	45.820	42.479
0.300	24.060	19.471	0.200	6.720	14.790
0.400	49.750	56.282	0.250	7.450	6.318
0.500	19.810	18.553	0.350	2.000	2.086
0.650	4.460	4.187	0.500	0.780	0.753

$$pr3 = (3.486032r^2 - 2.776123r + 0.5704517)^{-1}$$

$$pr4 = (9.318633r^2 - 2.380113r + 0.1708885)^{-1}$$

Table 4.6 Observed vs predicted frequency of trips for neighbourhood cluster.

ZONE 5 / ZONE 6

Dist r in Km	Observd	Predictd 'pr5'	Dist r in Km	Observd	Predictd 'pr6'
Ø.15Ø	Ø.Ø5Ø	3.481	Ø.235	5.ØØØ	4.947
Ø.25Ø	6.31Ø	6.198	Ø.325	6.ØØØ	7.874
Ø.3ØØ	5.37Ø	8.8Ø5	Ø.355	11.ØØØ	9.328
Ø.35Ø	13.66Ø	13.154	Ø.475	17.ØØØ	18.391
Ø.45Ø	37.25Ø	32.Ø87	Ø.595	24.ØØØ	22.915
Ø.55Ø	3Ø.8ØØ	37.125	Ø.655	19.ØØØ	18.499
Ø.8ØØ	5.84Ø	5.158	Ø.715	12.ØØØ	13.333
			Ø.865	6.ØØØ	5.767

$$pr5 = (2.028332r^2 - 2.070626r + 0.5522096)^{-1}$$

$$pr6 = (1.461620r^2 - 1.653388r + 0.5099530)^{-1}$$

ZONE 7

Dist r in Km	Observd	Predictd 'pr7'
Ø.4ØØ	6.ØØØ	15.631
Ø.45Ø	14.ØØØ	2Ø.732
Ø.5ØØ	36.ØØØ	25.945
Ø.6ØØ	2Ø.ØØØ	26.815
Ø.7ØØ	17.ØØØ	16.6Ø5
Ø.85Ø	5.ØØØ	7.144
1.25Ø	2.ØØØ	1.615

$$pr7 = (1.209106r^2 - 1.342521r + 0.4075249)^{-1}$$

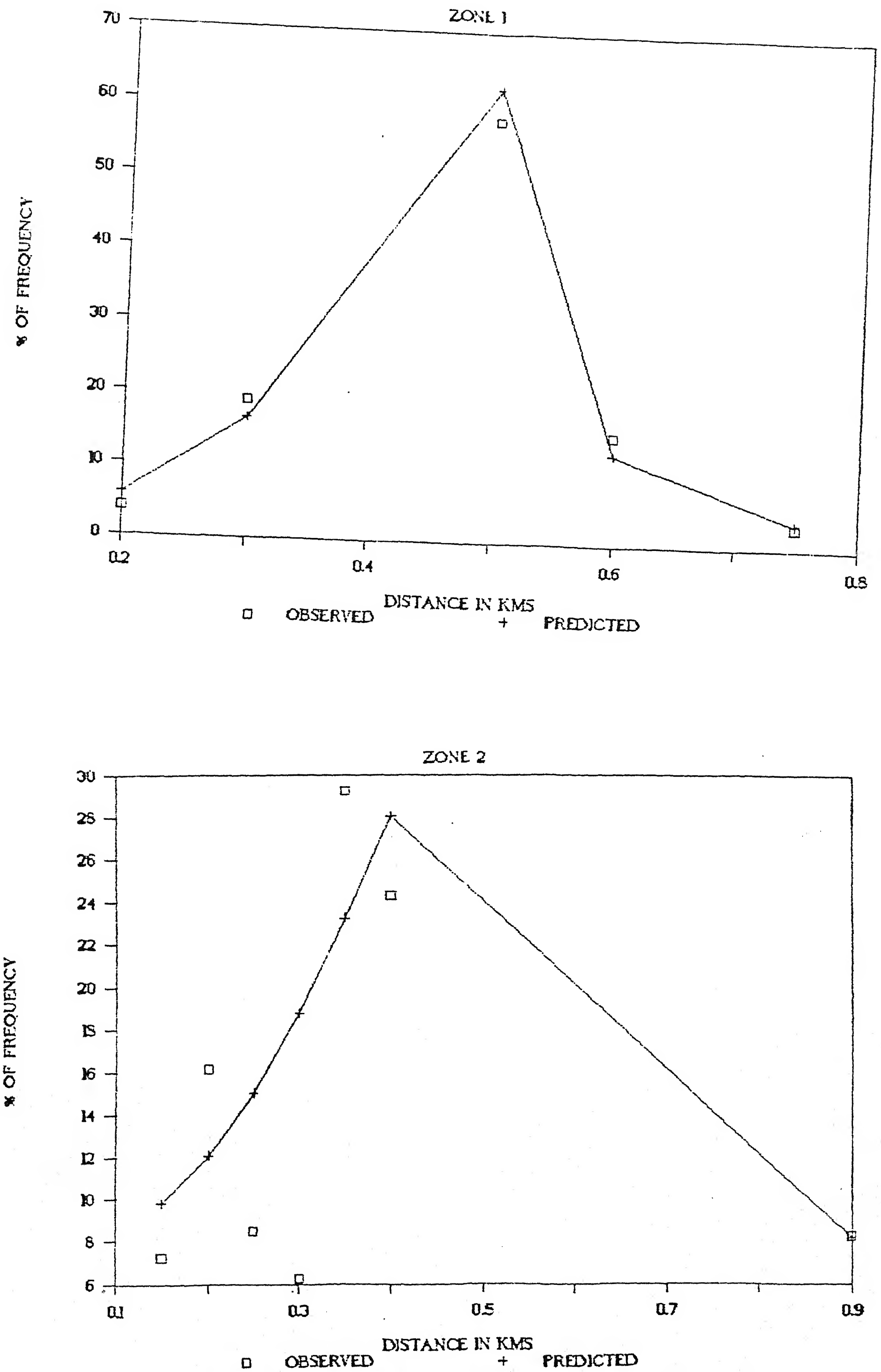
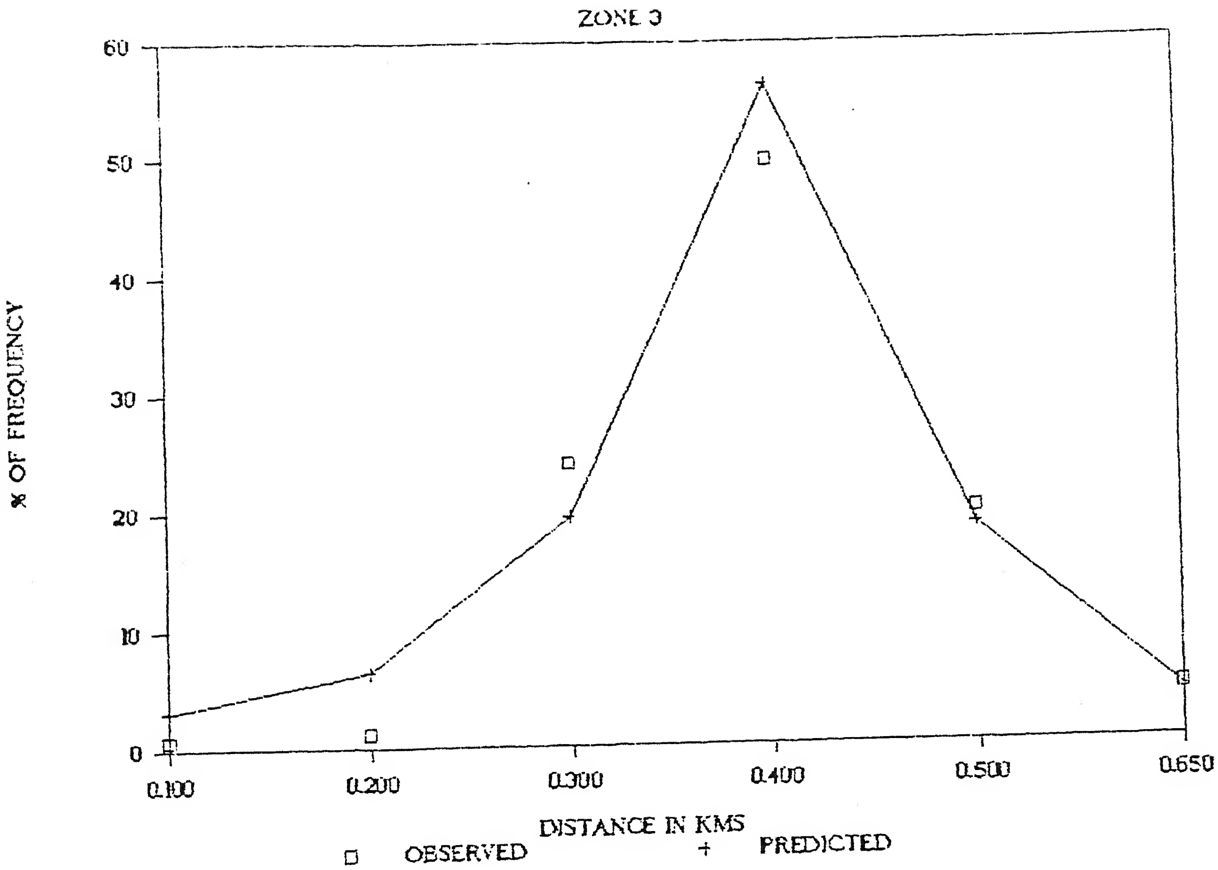


FIG. 4.5 Neighbourhood Calibration Zone 1 and 2



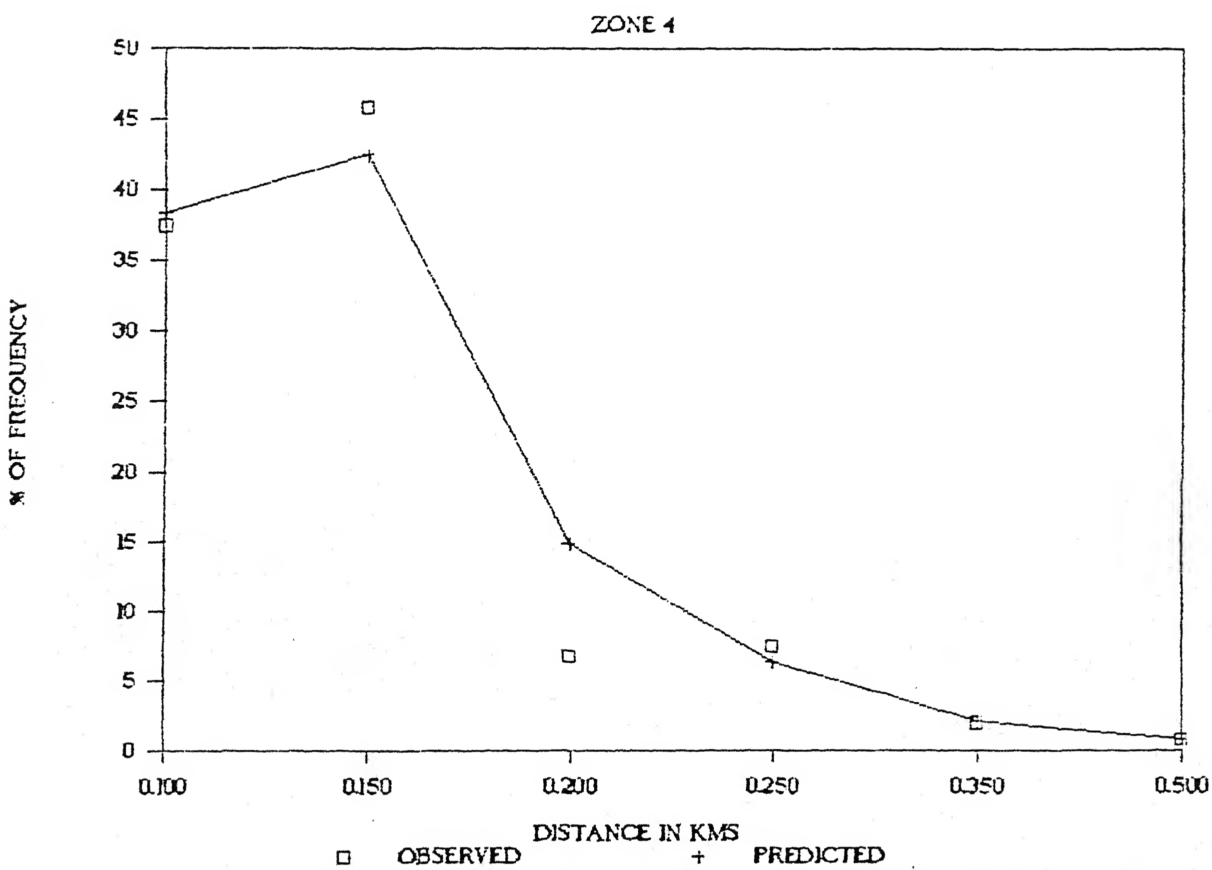
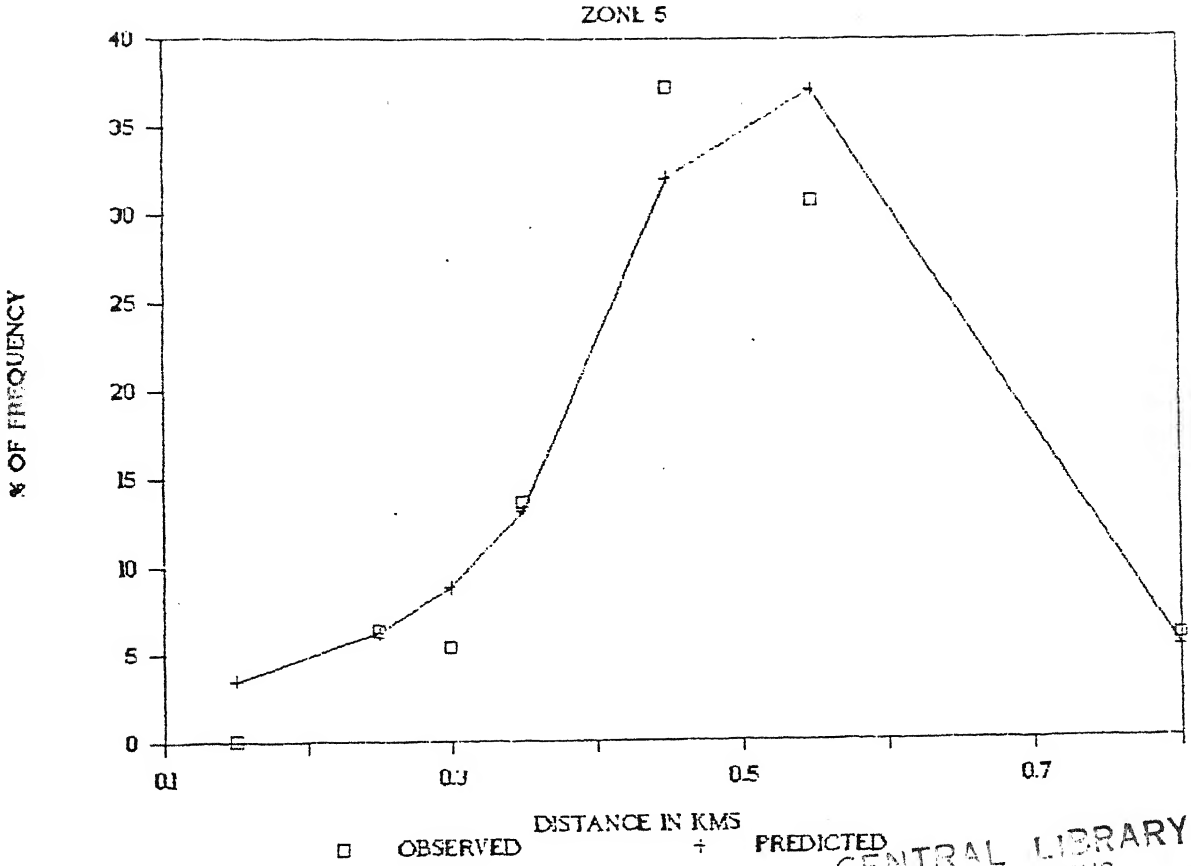


FIG. 4.6 Neighbourhood Calibration Zone 3 and 4



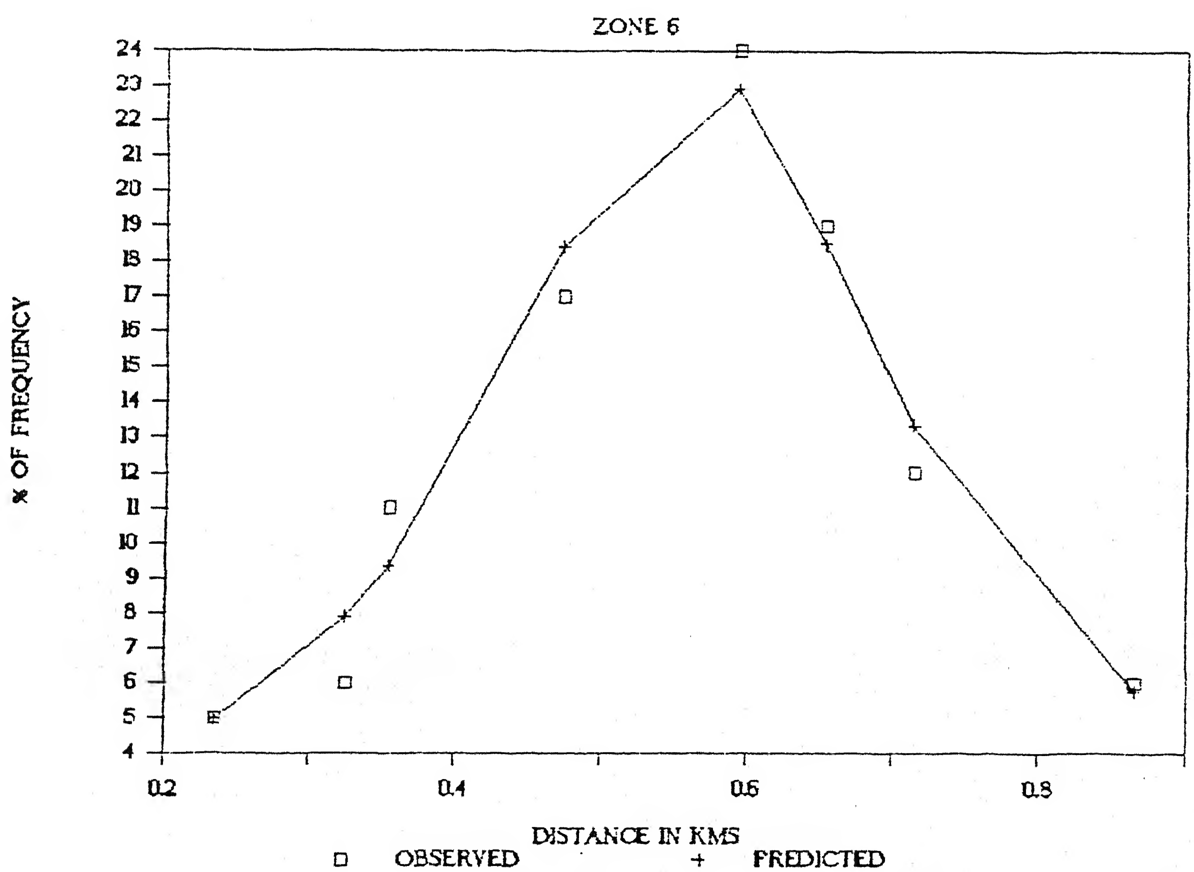


FIG. 4.7 Neighbourhood Calibration Zone 5 and 6

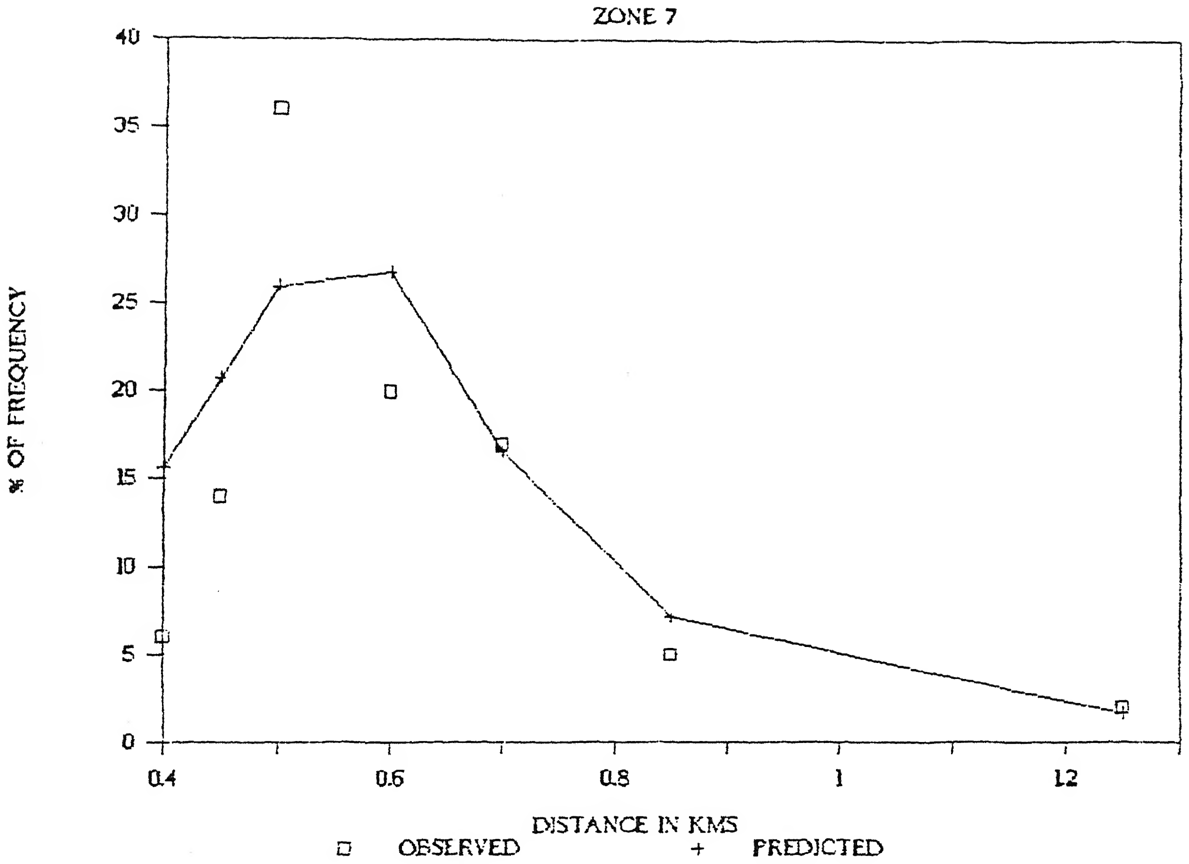


FIG. 4.8 Neighbourhood Calibration Zone 7

be a neighbourhood service trip. It is rational. By considering internal trips produced in each chak, the indices for the neighbourhood service are generated. The procedure adopted to find the predicted frequency of trip for work will be the same as that used in the work trip calibration. The trip indices for neighbourhood cluser in each zone is given below.

Zone	**Neighbourhood**	
1	$2.872242r^2 - 2.520618 0r - 0.5582693$	(Table 4.5, Fig 4.5)
2	$0.583087r^2 - 0.5850788r + 0.1763939$	(Table 4.5, Fig 4.5)
3	$3.486032r^2 - 2.7761230r + 0.5704517$	(Table 4.5, Fig 4.6)
4	$9.318633r^2 - 2.3801130r + 0.1708885$	(Table 4.5, Fig 4.6)
5	$2.028332r^2 - 2.0706260r + 0.5522096$	(Table 4.6, Fig 4.7)
6	$1.461620r^2 - 1.6533880r + 0.5099530$	(Table 4.6, Fig 4.7)
7	$1.209106r^2 - 1.3425210r + 0.4075249$	(Table 4.6, Fig 4.8)

4.5.2 Local cluster

First a disaggregated trip of home based shopping, primary, upper primary, secondary school trips for each chak inside each zone are computed. Because most of the local cluster trips belong to this category. A frequency distribution table based on distance with a range of 0.5 km is framed. Having found out this observed frequency of trips for local cluster, predicted frequency is calibrated. The trip indices in each zone is given in page 60.

Zone	**Local**	
1	$0.1494906r^2 - 0.5100302r + 0.4486036 0$	(Table 4.7, Fig 4.9)

Table 4·7 Observed vs predicted frequency of trip for the local cluster

ZONE 1 / ZONE 2

Dist r in Km	Observd	Predictd 'pr1'	Dist r in Km	Obserevd	Pridictd 'pr2'
1.000	6.340	11.355	0.500	6.930	9.155
1.500	57.620	50.221	1.000	19.470	20.078
2.000	24.250	37.728	1.500	48.100	41.695
2.500	11.700	9.272	2.000	12.130	19.293
3.000	0.090	3.788	2.500	5.630	7.499
			3.000	3.170	3.723
			3.500	3.080	2.186
			4.000	1.440	1.428

$$pr1 = (0.1494906r^2 - 0.5100302r + 0.4486030)^{-1}$$

$$pr2 = (0.1073365r^2 - 0.3199823r + 0.2524499)^{-1}$$

ZONE 3 / ZONE 4

Dist r in Km	Observd	Predictd 'pr3'	Dist r in Km	Observd	Predictd 'pr4'
0.500	1.240	3.818	0.500	36.400	37.284
1.000	13.010	10.747	1.000	37.900	35.808
1.500	51.060	53.689	1.500	14.220	15.650
2.000	25.300	25.857	2.000	6.210	7.357
2.500	8.030	5.529	2.500	5.010	4.121
3.000	1.360	2.751	3.000	0.250	2.598

$$pr3 = (0.1889020r^2 - 0.5210898r + 0.5252308)^{-1}$$

$$pr4 = (0.7046490r^2 - 0.1034863r + 0.0609479)^{-1}$$

Table 4.8 Observed vs predicted frequency of trip for the local cluster

ZONE 5 | Zone 6

Dist r in Km	Observd	Predictd 'pr5'	Dist r in Km	Observd	Predictd 'pr6'
0.500	1.220	12.399	0.500	13.310	9.608
1.000	23.470	19.247	1.000	12.260	18.823
1.500	13.270	24.954	1.500	16.840	31.332
2.000	23.730	22.219	2.000	28.120	24.725
2.500	15.640	14.981	2.500	15.740	12.704
3.000	7.880	9.496	3.000	7.690	6.815
3.500	6.410	6.223	3.500	3.140	4.090
4.000	5.970	4.294	4.000	1.950	2.688
4.500	1.580	3.107	4.500	0.080	1.889
5.000	0.840	2.338	5.000	0.850	1.896

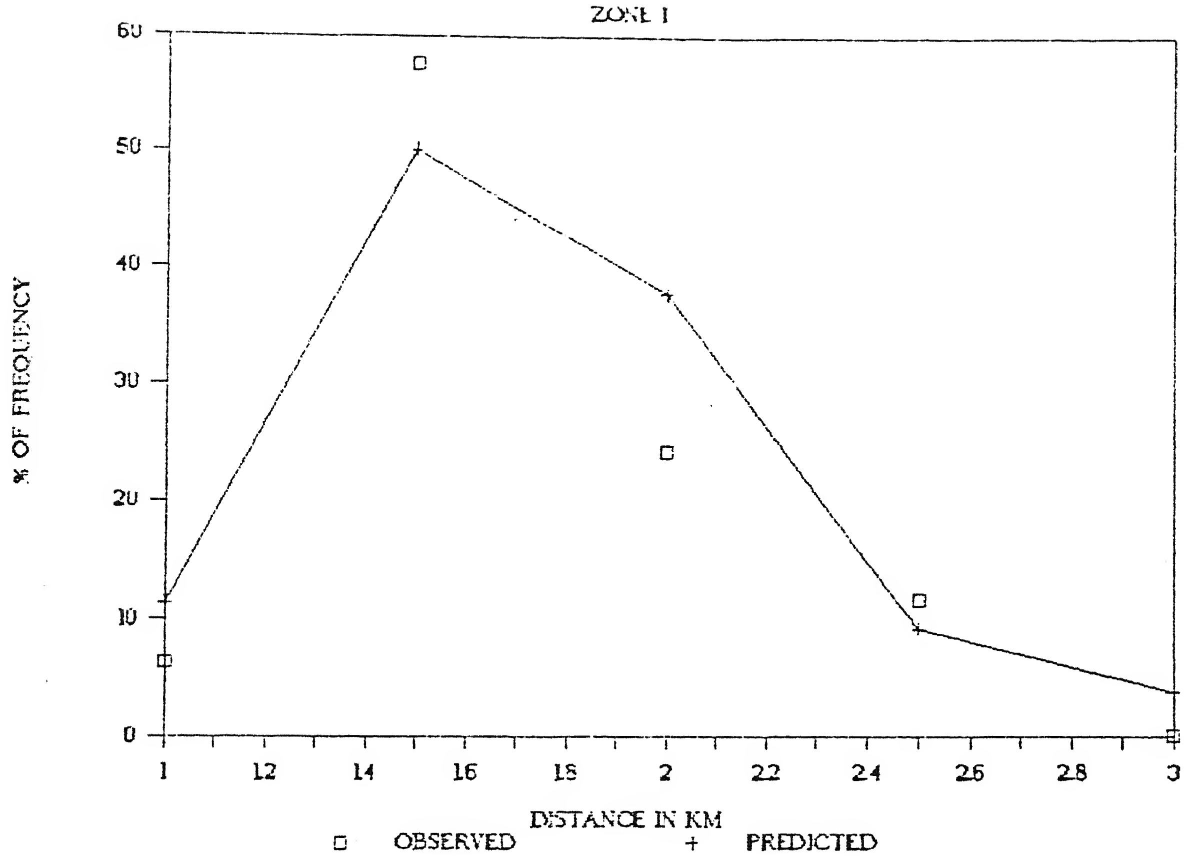
$$pr5 = (0.0336237r^2 - 0.1078199r + 0.1261501)^{-1}$$

$$pr6 = (0.0594757r^2 - 0.1911065r + 0.1847540)^{-1}$$

ZONE 7

Dist r in Km	Observd	Predictd 'pr7'
1.000	6.580	13.440
1.500	39.620	30.942
2.000	13.300	27.019
2.500	20.180	14.248
3.000	15.670	10.838
3.500	3.640	5.737
4.000	0.350	3.479
4.500	0.090	2.317
5.000	0.090	1.648

$$pr7 = (0.0620627r^2 - 0.2393202r + 0.2516572)^{-1}$$



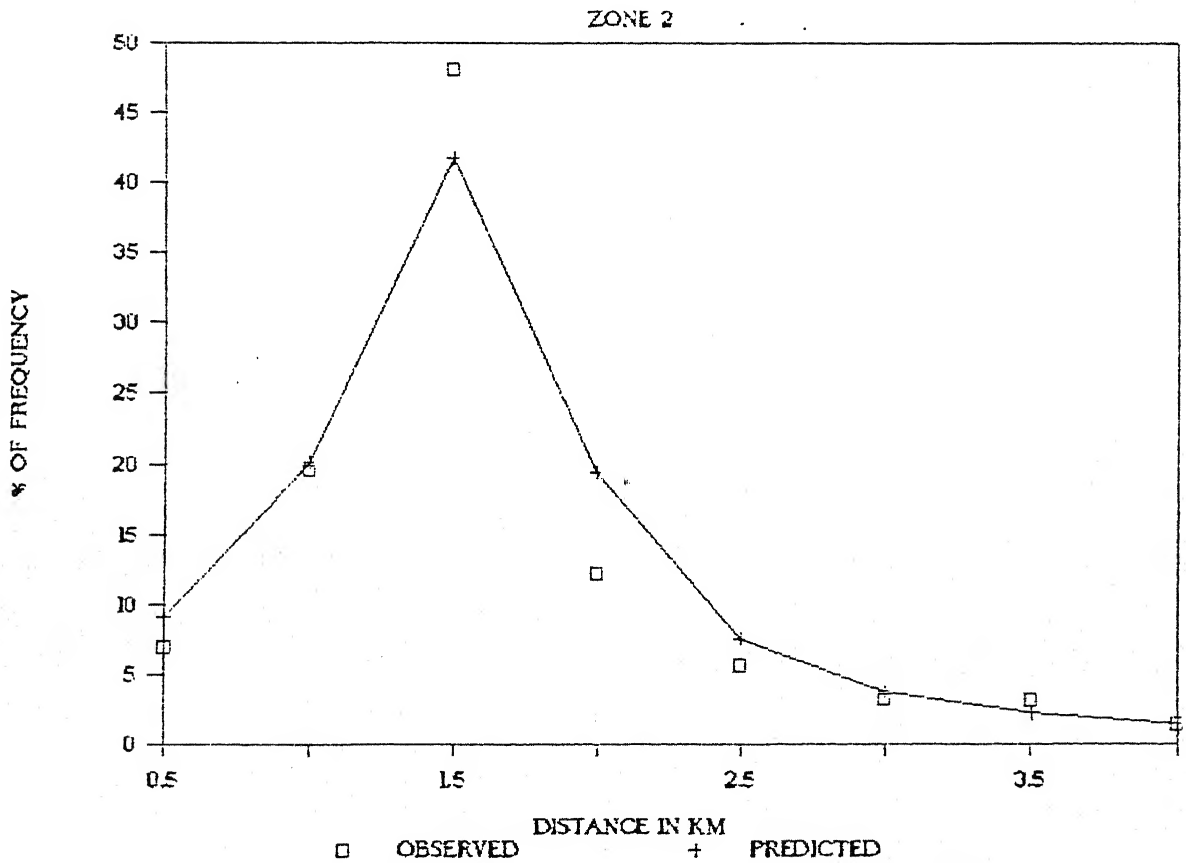
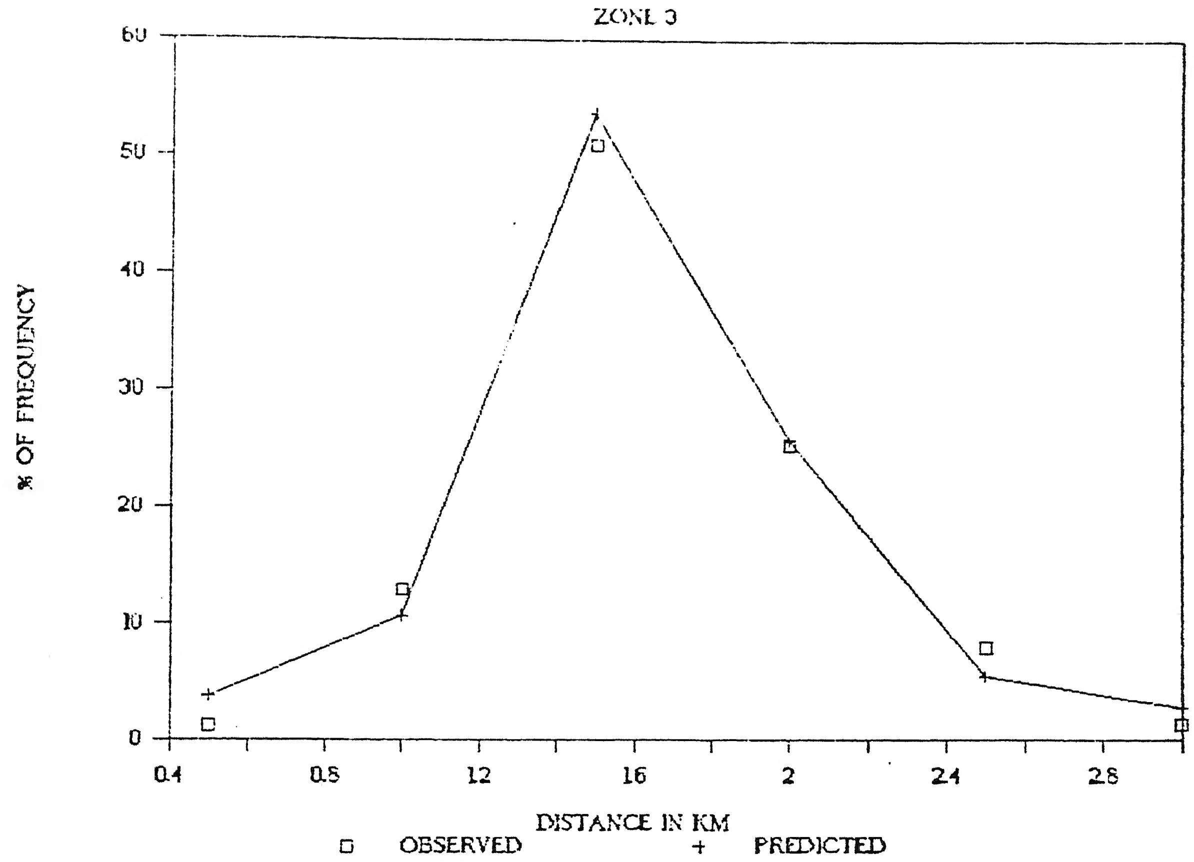


FIG. 4.9 Calibration of Local Trip Zone 1 and 2



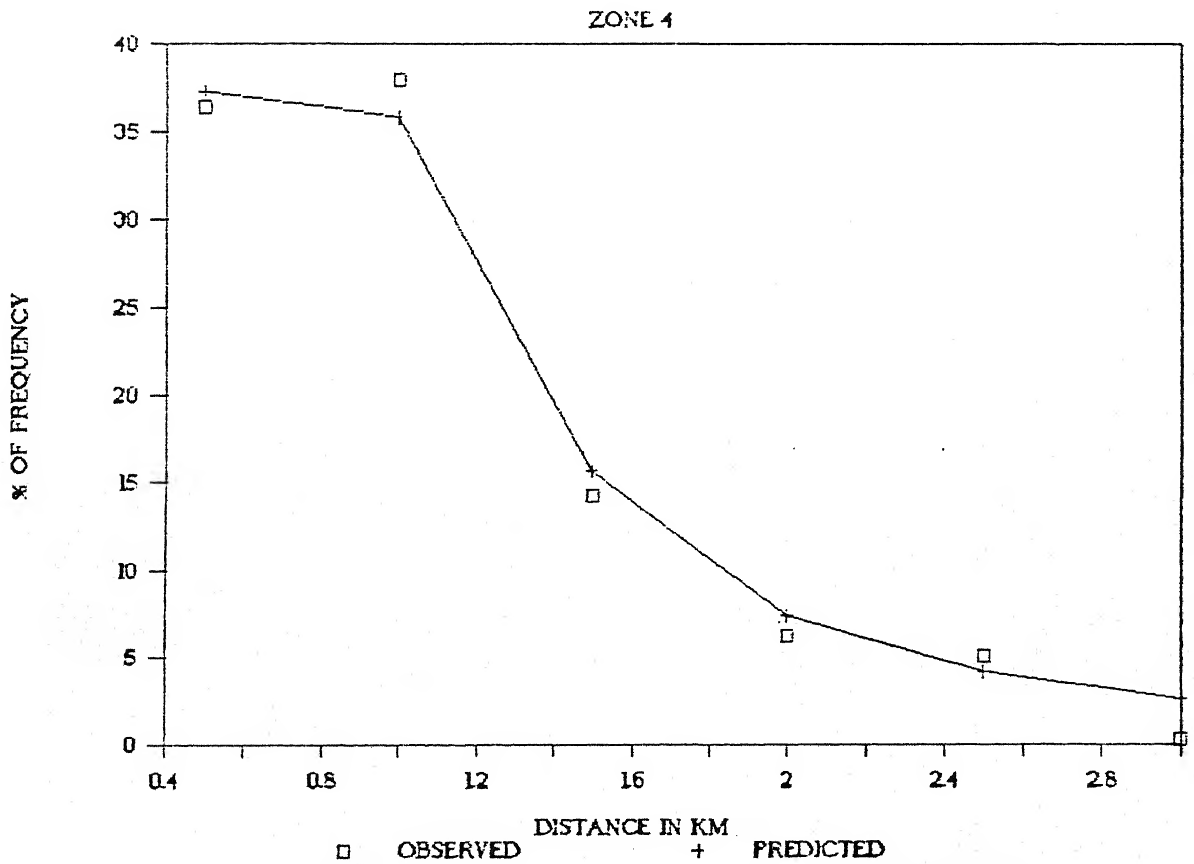


FIG. 4.10 Calibration of Local Trip Zone 3 and 4

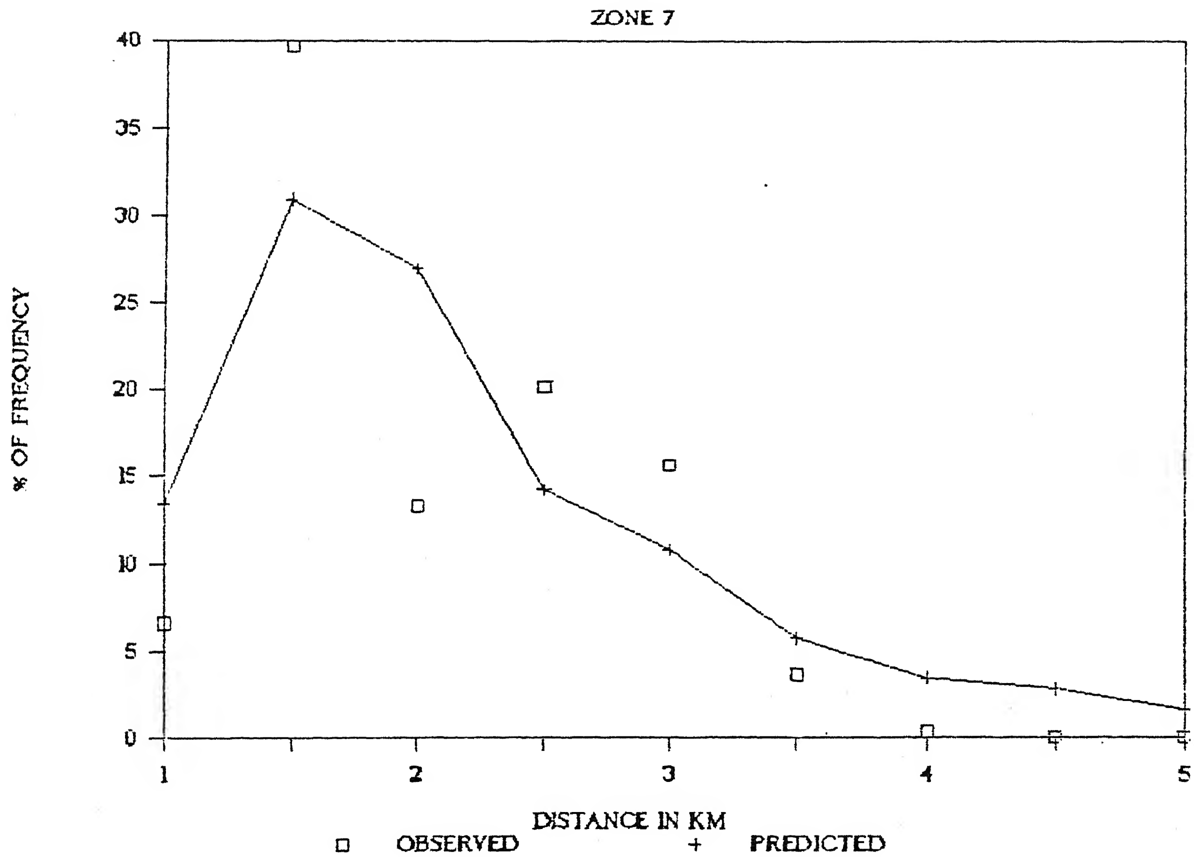


FIG. 4.12 Calibration of Local Trip Zone 7

2	$0.1033650r^2 - 0.3199823r + 0.25244990$	(Table 4.7, Fig 4.9)
3	$0.1889020r^2 - 0.5210898r + 0.52523080$	(Table 4.7,Fig 4.10)
4	$0.0704649r^2 - 0.1034863r + 0.06094795$	(Table 4.7,Fig 4.10)
5	$0.0336237r^2 - 0.1078199r + 0.12615010$	(Table 4.8,Fig 4.11)
6	$0.0594757r^2 - 0.1911065r + 0.18475400$	(Table 4.8,Fig 4.11)
7	$0.0620627r^2 - 0.2393202r + 0.25165720$	(Table 4.8,Fig 4.12)

4.5.3 Metropolitan clusters

Most of the long distance trips performed belong to the category of metropolitan cluster. The long distance education trips, under graduate, post graduate, professional educational trip, long distance shopping, recreational are all belong to this category. The indices are given below.

Zone	Metropolitan	
1	$0.04829700r^2 - 0.13780010r + 0.1272116$	(Table 4.9,Fig 4.13)
2	$0.01384584r^2 - 0.05750578r + 0.1142229$	(Table 4.9,Fig 4.13)
3	$0.02192518r^2 - 0.09409453r + 0.1641287$	(Table 4.10,Fig 4.14)
4	$0.03964614r^2 - 0.05946471r + 0.0559485$	(Table 4.10,Fig 4.14)
5	$0.02685535r^2 - 0.11562490r + 0.1833145$	(Table 4.11,Fig 4.15)
6	$0.02764564r^2 - 0.12983900r + 0.2182283$	(Table 4.11,Fig 4.15)
7	$0.02486932r^2 - 0.12744440r + 0.2211798$	(Table 4.12,Fig 4.16)

4.5.4 Minimum Size Constraints (Z^k)

Controlling the distribution of employment was anticipated as a major problem in model design. The difficulty is that the potential functions do not allow for those external economies of scale which encourage the clustering of retail establishments.

Table 4.9 Observed vs predicted frequency of trip for the metropolitan cluster

ZONE 1			ZONE 2		
Dist r in Km	Observd	Predictd 'pr1'	Dist r in Km	Observd	Predictd 'pr2'
0.500	3.413	14.207	1.000	2.774	14.171
1.000	36.721	26.518	1.500	25.513	16.915
1.500	17.276	34.269	2.000	11.508	18.315
2.000	8.607	22.320	2.500	5.643	17.545
2.500	8.101	11.824	3.000	5.459	15.078
3.000	5.861	6.734	3.500	7.456	12.111
3.500	6.501	4.227	4.000	4.979	9.457
4.000	3.953	2.857	4.500	6.192	7.352
4.500	2.752	2.051	5.000	6.366	5.785
5.000	1.442	1.548	5.500	8.025	4.613
5.500	0.947	1.204	6.000	5.375	3.736
6.000	0.840	0.952	6.500	1.288	3.072
6.500	1.031	0.786	7.000	1.486	2.563
7.000	0.995	0.653	7.500	0.867	2.165
7.500	0.274	0.552	8.000	2.972	1.850
8.000	0.137	0.472	8.500	0.991	1.597
8.500	0.137	0.408	9.000	0.743	1.392
9.000	0.119	0.357	9.500	0.718	1.223
9.500	0.191	0.314	10.500	0.025	0.954
10.000	0.240	0.279	12.500	0.099	0.641
10.500	0.151	0.249	13.000	0.149	0.685
11.000	0.143	0.224	13.500	0.099	0.537
11.500	0.066	0.202	14.000	0.050	0.494
12.000	0.089	0.184	14.500	0.223	0.455

$$pr1 = (0.0482970r^2 - 0.1378001r + 0.1272116)^{-1}$$

$$pr2 = (0.0138548r^2 - 0.0575057r + 0.1142230)^{-1}$$

Table 4.10 Observed vs predicted frequency of trip for the metropolitan cluster

ZONE 3			ZONE 4		
Dist r in Km	Observd	Predictd 'pr3'	Dist r in Km	Observd	Predictd 'pr4'
0.500	0.679	8.149	0.500	29.391	27.679
1.000	7.356	10.874	1.000	30.600	27.677
1.500	20.080	13.827	1.500	11.485	17.871
2.000	10.880	15.713	2.000	5.016	10.459
2.500	14.290	15.168	2.500	4.048	5.448
3.000	10.680	12.630	3.000	5.175	4.255
3.500	8.741	9.672	3.500	3.660	2.998
4.000	5.023	7.217	4.000	1.676	2.210
4.500	4.268	5.414	4.500	1.823	1.691
5.000	2.867	4.135	5.000	1.828	1.333
5.500	4.408	3.227	5.500	1.826	1.077
6.000	3.654	2.571	6.000	1.228	0.887
6.500	2.781	2.088	6.500	0.390	0.743
7.000	2.457	1.725	7.000	0.205	0.631
7.500	0.071	1.445	7.500	0.120	0.543
8.000	0.022	1.227	8.000	0.252	0.472
8.500	0.205	1.054	8.500	0.270	0.414
9.000	0.152	0.914	9.000	0.325	0.366
9.500	0.235	0.800	9.500	0.305	0.325
10.000	0.237	0.706	10.000	0.199	0.291
11.000	0.108	0.561	10.500	0.073	0.252
11.500	0.054	0.504	11.000	0.023	0.238
12.000	0.022	0.455	11.500	0.015	0.215
12.500	0.055	0.414	12.000	0.050	0.197
			12.500	0.012	0.181
			13.000	0.003	0.157

$$pr3 = (0.0219251r^2 - 0.0940945r + 0.1641280)^{-1}$$

$$pr4 = (0.0396461r^2 - 0.0594647r + 0.0559480)^{-1}$$

Table 4.11 Observed vs predicted frequency of trip for the metropolitan cluster

ZONE 5			ZONE 6		
Dist r in Km	Observd	Predictd 'pr5'	Dist r in Km	Observd	Predictd 'pr6'
0.500	1.984	7.553	0.500	5.985	6.241
1.000	15.796	10.576	1.000	9.341	8.618
1.500	11.358	14.224	1.500	12.234	11.673
2.000	16.317	16.810	2.000	17.379	14.454
2.500	9.940	16.103	2.500	10.696	15.056
3.000	5.453	12.797	3.000	5.873	12.899
3.500	7.663	9.293	3.500	8.746	9.750
4.000	7.755	6.644	4.000	8.725	7.082
4.500	3.944	4.835	4.500	3.347	5.150
5.000	4.562	3.615	5.000	3.968	3.843
5.500	4.512	2.779	5.500	3.152	2.937
6.000	2.878	2.191	6.000	2.356	2.301
6.500	1.585	1.765	6.500	2.248	1.843
7.000	1.342	1.449	7.000	2.443	1.505
7.500	0.911	1.209	7.500	0.593	1.250
8.000	1.447	1.023	8.000	0.195	1.053
8.500	0.519	0.876	8.500	0.369	0.899
9.000	0.149	0.758	9.000	1.229	0.775
9.500	0.358	0.652	9.500	0.253	0.675
10.000	0.652	0.583	10.000	0.173	0.593
10.500	0.011	0.518	10.500	0.304	0.525
11.000	0.304	0.452	11.000	0.108	0.468
11.500	0.265	0.415	11.500	0.094	0.419
12.000	0.083	0.375	12.000	0.072	0.378
12.500	0.066	0.340	12.500	0.014	0.348
13.000	0.061	0.310	13.000	0.029	0.312
13.500	0.050	0.284	13.500	0.036	0.285
14.000	0.028	0.251	14.000	0.036	0.241
14.500	0.011	0.240			

$$pr5 = (0.0268553r^{r} - 0.1156249r + 0.1833145)^{-1}$$

$$pr6 = (0.0276456r^{2} - 0.1298390r + 0.2182283)^{-1}$$

Table 4.12 Observed vs predicted frequency of trip for the metropolitan cluster

ZONE 7

Dist r in Km	Observd	Predictd 'pr'
1.000	5.850	8.431
1.500	18.471	11.632
2.000	8.446	15.205
2.500	11.812	17.240
3.000	8.418	15.956
3.500	7.648	12.535
4.000	11.676	9.448
4.500	5.252	6.610
5.000	4.624	4.851
5.500	3.799	3.659
6.000	3.353	2.842
6.500	3.716	2.254
7.000	3.072	1.825
7.500	0.776	1.505
8.000	0.859	1.250
8.500	0.578	1.059
9.000	0.644	0.918
9.500	0.254	0.796
10.000	0.099	0.697
10.500	0.017	0.615
11.000	0.017	0.545
11.500	0.099	0.489
12.000	0.099	0.489
12.500	0.116	0.397
13.500	0.099	0.329
14.000	0.182	0.301
15.000	0.017	0.256

$$pr7 = (0.0248693r^2 - 0.1274444r + 0.2211798)^{-1}$$

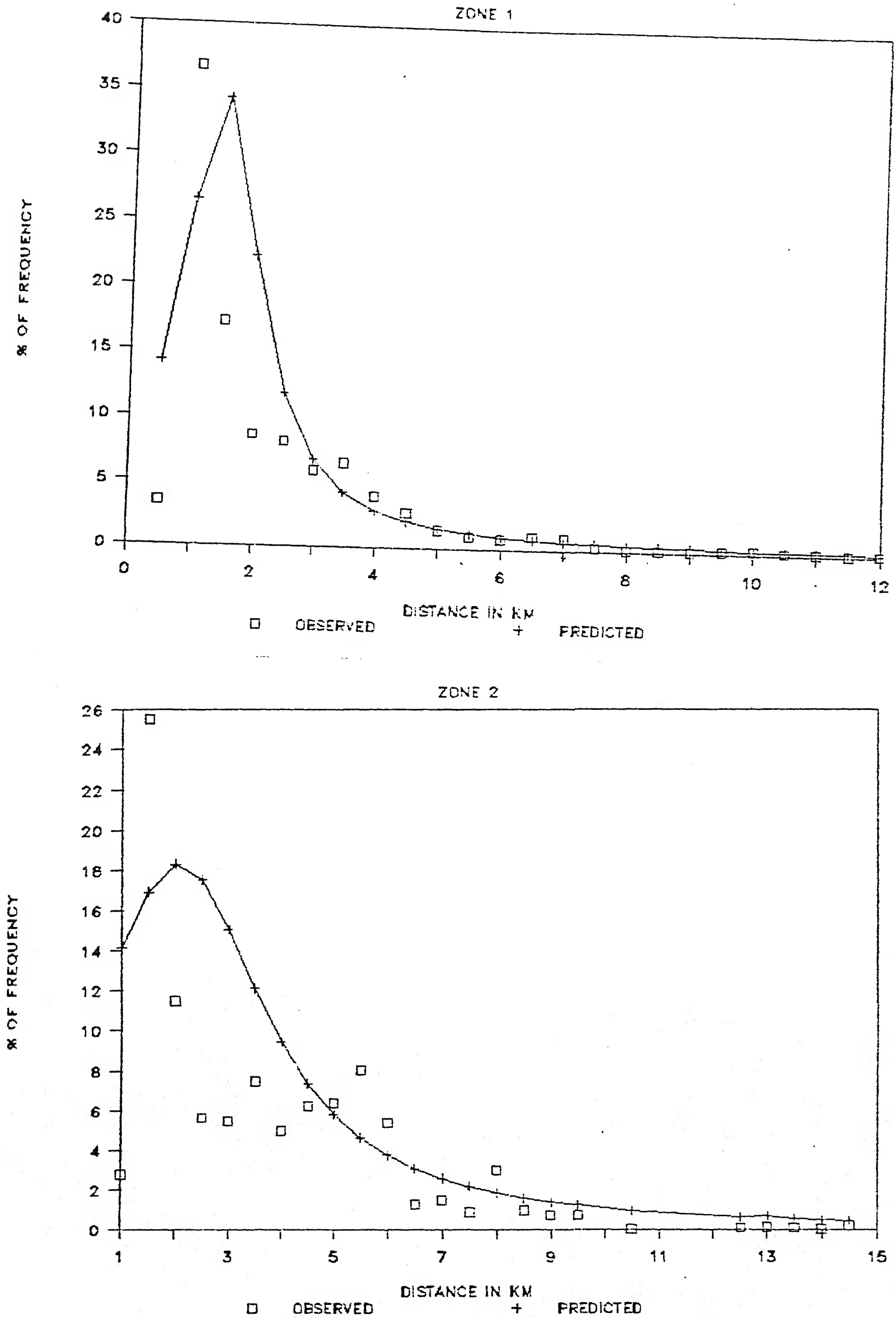


FIG. 4.13 Calibration of Metropolitan Trip Zone 1 and 2

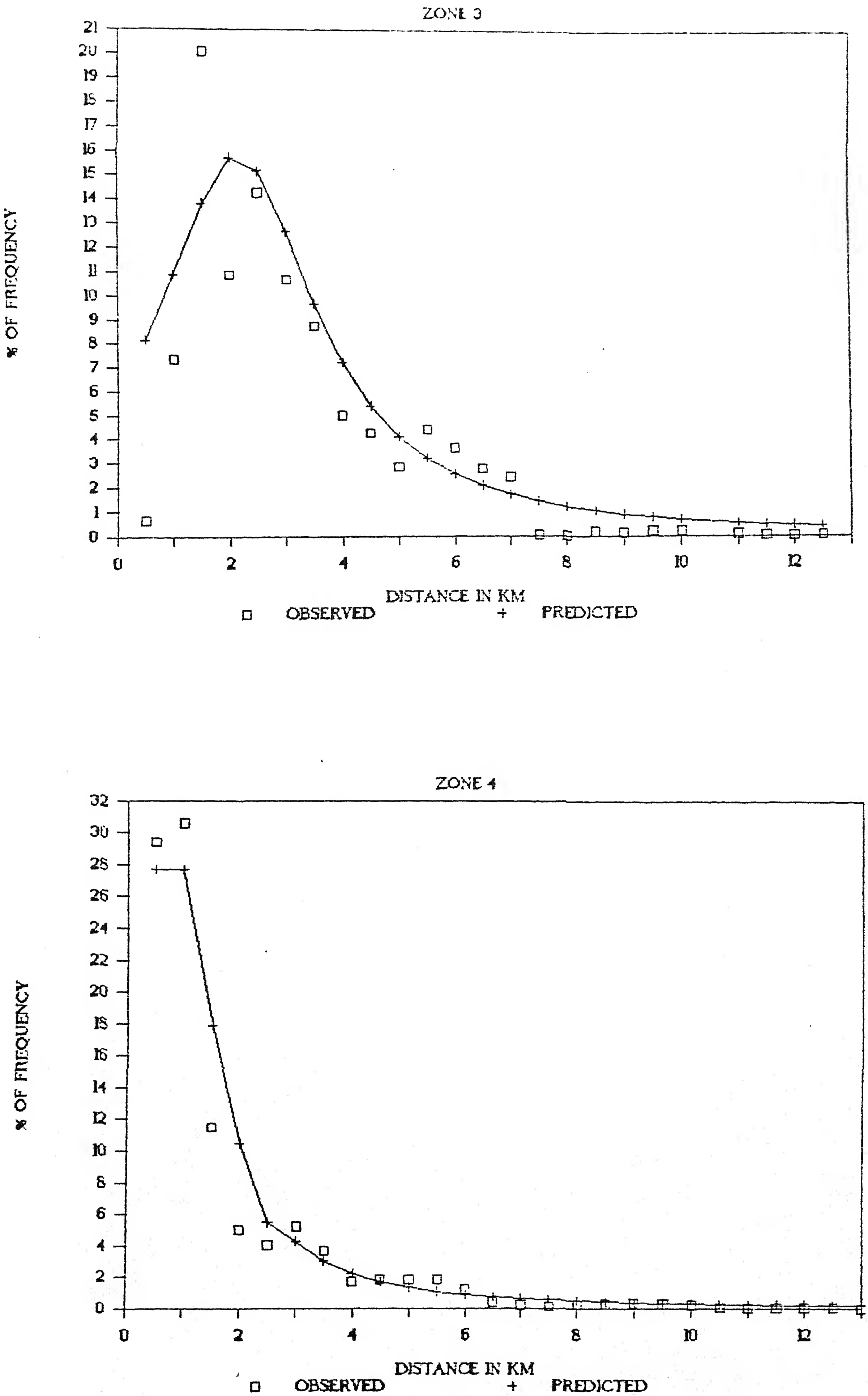
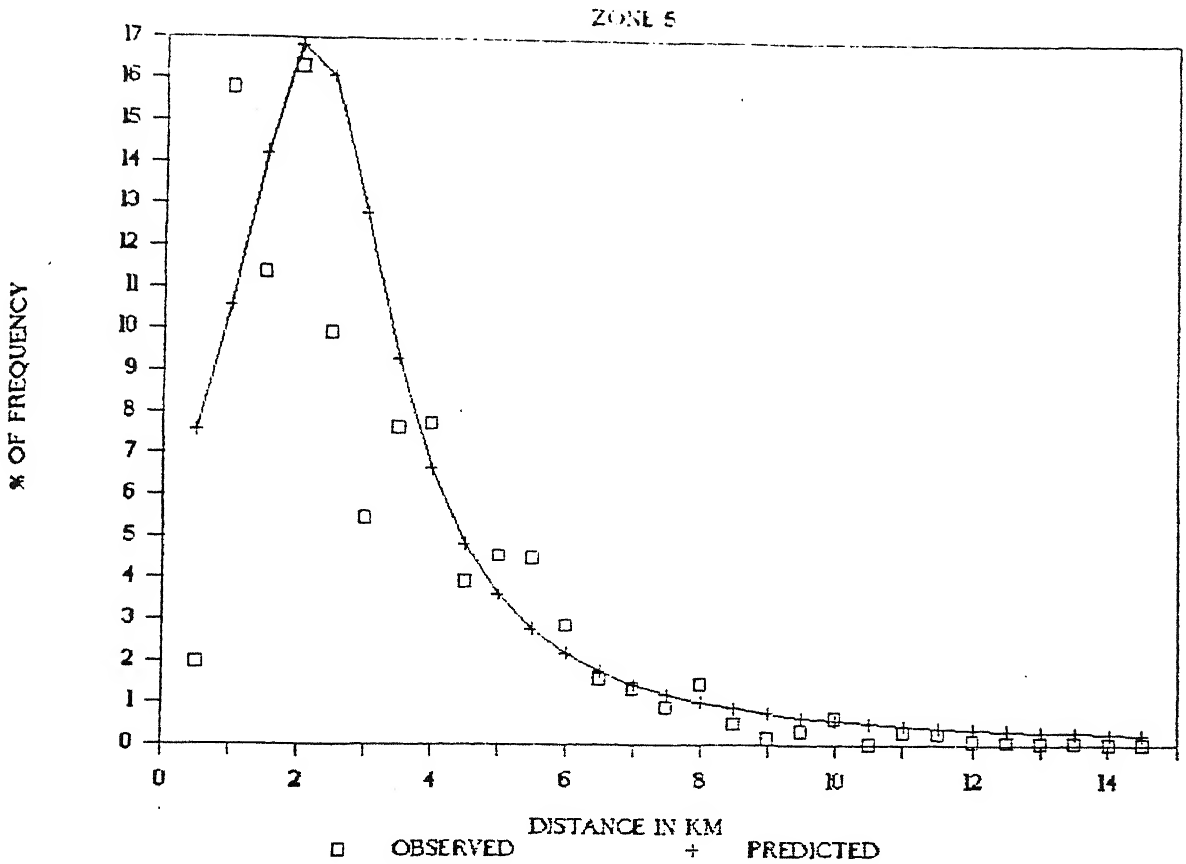


FIG. 4.14 Calibration of Metropolitan Trip Zone 3 and 4



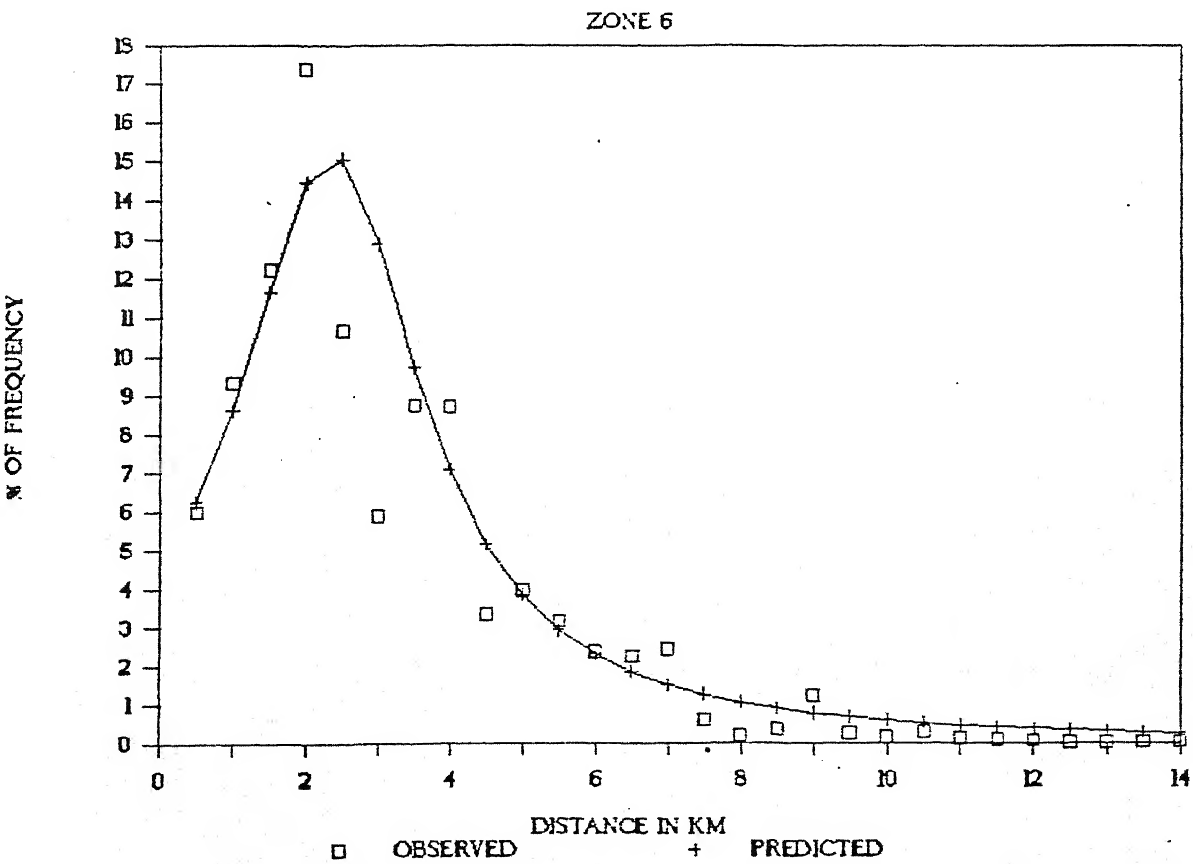


FIG. 4.15 Calibration of Metropolitan Trip Zone 5 and 6

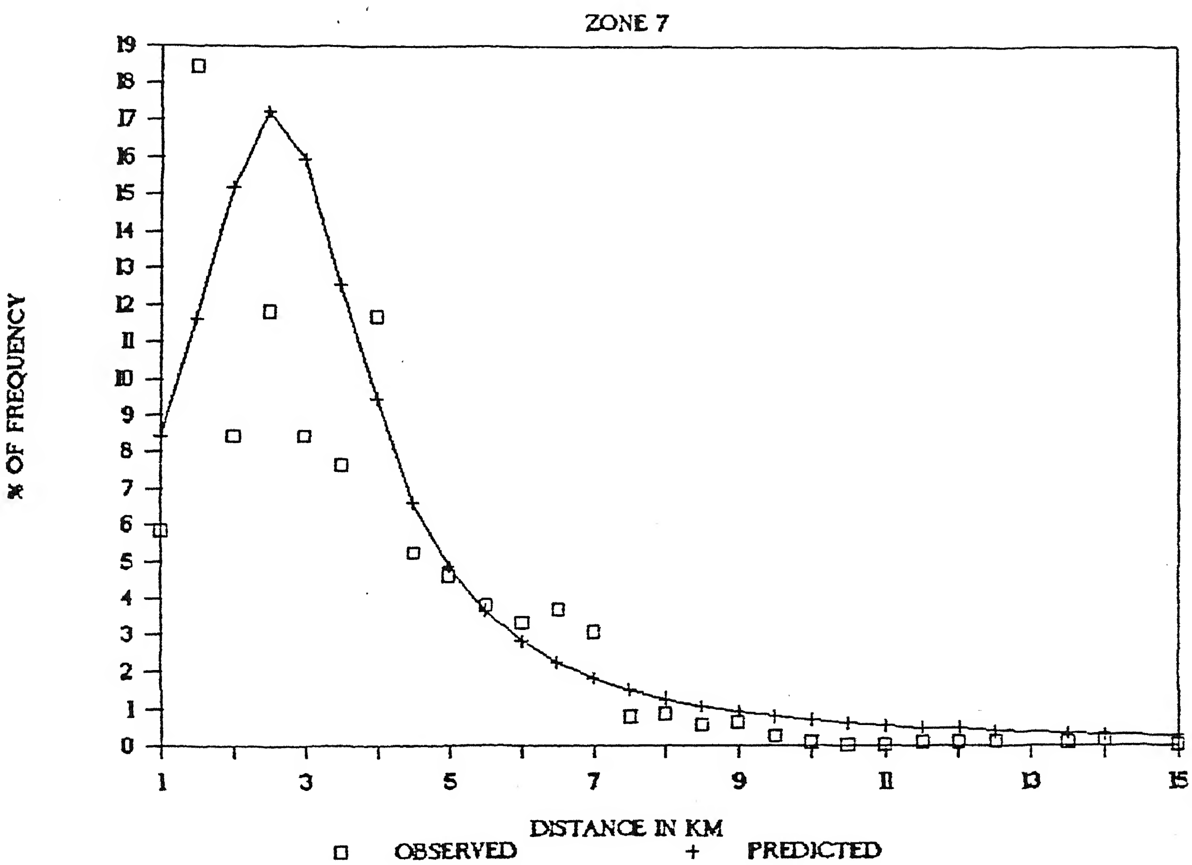


FIG. 4.16 Calibration of Metropolitan Trip Zone 7

Table 4.13 Observed vs predicted frequency of trip for colleges

ZONE 1			ZONE 2		
Dist r in Km	Observd	Predictd 'pr'	Dist r in Km	Observd	Predictd 'pr'
0.500	20.000	18.343	0.500	15.190	14.550
1.500	23.510	20.088	1.000	19.390	15.858
2.000	4.330	19.652	1.500	11.450	15.747
2.500	4.120	18.438	2.000	7.940	14.282
3.000	3.710	16.692	2.500	10.000	12.107
3.500	5.150	14.732	3.000	8.900	9.877
4.000	1.030	12.796	3.500	9.860	7.930
4.500	16.290	11.023	4.000	6.800	6.380
5.000	5.150	9.471	4.500	7.540	5.156
5.500	11.960	8.147	5.000	1.530	4.228
6.000	2.270	7.032	5.500	0.400	3.503
8.000	1.650	4.115	6.000	0.170	2.936
8.500	0.210	3.650	6.500	0.280	2.490
9.000	0.410	3.256	7.000	0.091	2.188
			9.000	0.050	1.252
			9.500	0.050	1.115
			10.000	0.050	1.000

$$Pr1 = (0.0045949r^2 - 0.0139260r + 0.0603306)^{-1}$$

$$pr2 = (0.0121328r^2 - 0.0294420r + 0.8036637)^{-1}$$

ZONE 3			ZONE 4		
Dist r in Km	Observd	Predictd 'pr3'	Dist r in Km	Observd	Predictd 'pr4'
1.500	37.680	36.610	0.500	9.280	7.752
2.000	10.510	14.936	1.000	19.810	15.209
2.500	10.140	8.741	1.500	15.580	31.671
3.000	1.090	5.891	2.000	10.810	38.030
3.500	6.160	4.292	2.500	18.550	20.035
4.000	2.540	3.289	3.000	16.520	9.753
4.500	0.720	2.610	3.500	5.270	5.439
5.000	0.360	2.128	4.000	1.690	3.399
5.500	1.450	1.771	4.500	0.660	2.307
8.000	1.000	0.854	5.000	0.440	1.652
			5.500	0.380	1.252
			7.000	0.110	0.639
			10.000	0.110	0.258

$$pr3 = (0.0157588 0r^2 - 0.0239301 8r - 0.0439860)^{-1}$$

$$pr4 = (0.0677943 0r^2 - 0.2128385 0r + 0.2207947)^{-1}$$

Table 4.14 Observed vs predicted frequency of trip for colleges

ZONE 5			ZONE 6		
Dist r in Km	Observd	predictd 'pr5'	Dist r in Km	Observd	Predictd 'pr6'
Ø.5ØØ	18.56Ø	16.284	Ø.5ØØ	2Ø.Ø3Ø	2Ø.135
1.5ØØ	9.45Ø	14.459	1.5ØØ	19.ØØØ	16.837
2.ØØØ	15.85Ø	13.Ø44	2.ØØØ	6.68Ø	14.355
2.5ØØ	4.ØØØ	11.636	2.5ØØ	13.53Ø	11.973
3.ØØØ	1.56Ø	1Ø.Ø84	3.ØØØ	4.51Ø	9.9Ø2
3.5ØØ	8.13Ø	8.752	3.5ØØ	1Ø.15Ø	8.193
4.ØØØ	5.56Ø	7.6Ø2	4.ØØØ	5.69Ø	6.815
4.5ØØ	4.54Ø	6.6Ø4	4.5ØØ	Ø.95Ø	5.715
5.ØØØ	5.96Ø	5.754	5.ØØØ	4.94Ø	4.834
5.5ØØ	8.Ø6Ø	5.Ø35	5.5ØØ	4.51Ø	4.127
6.ØØØ	5.55Ø	4.427	6.ØØØ	Ø.78Ø	3.654
6.5ØØ	3.12Ø	3.912	6.5ØØ	3.Ø4Ø	3.Ø35
7.ØØØ	3.65Ø	3.474	7.ØØØ	3.68Ø	2.7ØØ
7.5ØØ	3.24Ø	3.1ØØ	7.5ØØ	Ø.43Ø	2.38Ø
8.ØØØ	Ø.95Ø	2.78Ø	8.ØØØ	Ø.43Ø	2.111
8.5ØØ	Ø.34Ø	2.6Ø4	9.ØØØ	Ø.Ø9Ø	1.691
9.5ØØ	Ø.61Ø	2.Ø57			
1Ø.ØØØ	Ø.44Ø	1.875			

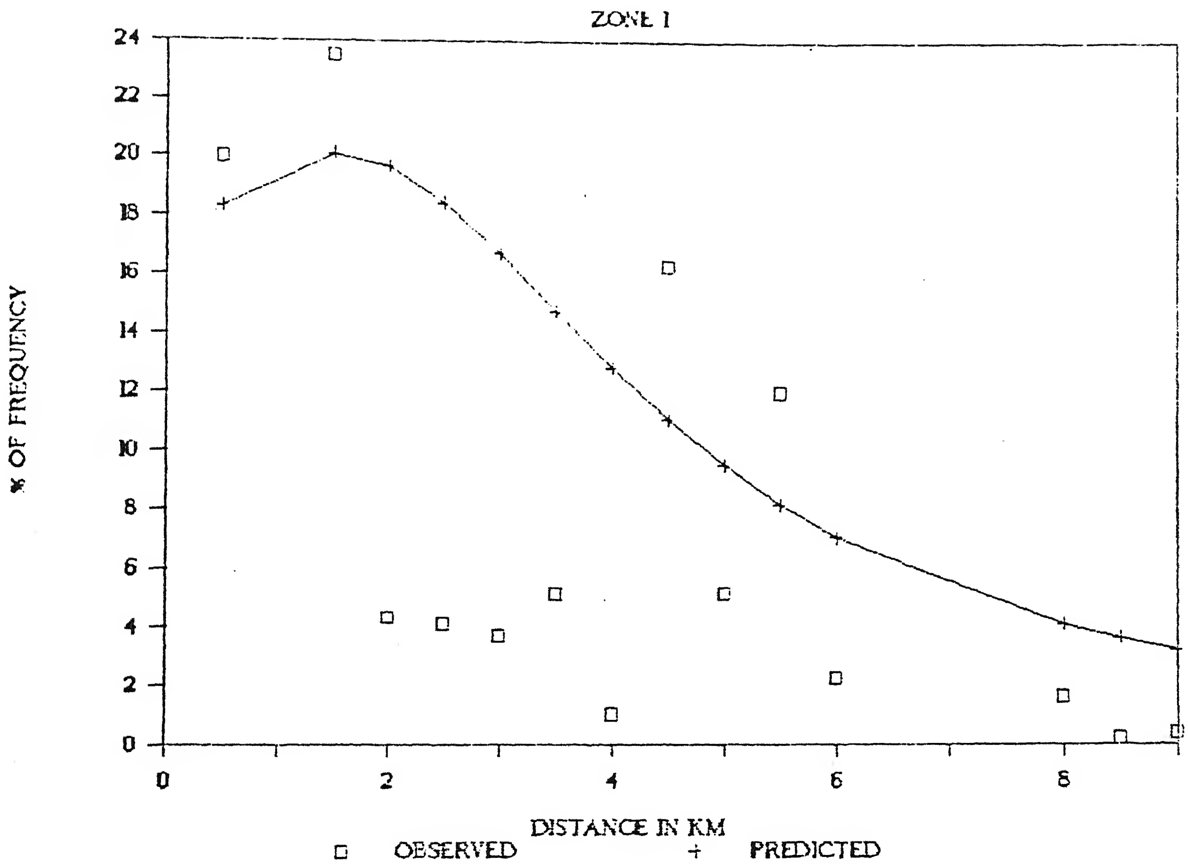
$$pr5 = (Ø.ØØ49331Ør^2 - Ø.ØØ216278r + Ø.22Ø794)^{-1}$$

$$pr6 = (Ø.ØØ72ØØ4r^2 - Ø.ØØ467514r + Ø.Ø5Ø2Ø2)^{-1}$$

ZONE 7

Dist r in Km	Observd	Predictd 'pr'
Ø.5ØØ	9.79Ø	8.2Ø1
1.5ØØ	12.5ØØ	1Ø.873
2.ØØØ	9.63Ø	11.677
2.5ØØ	8.83Ø	11.754
3.ØØØ	7.7ØØ	11.Ø77
3.5ØØ	9.31Ø	9.877
4.ØØØ	6.42Ø	8.475
4.5ØØ	2.41Ø	7.118
5.ØØØ	6.58Ø	5.925
5.5ØØ	9.47Ø	4.931
6.ØØØ	1.44Ø	4.122
7.ØØØ	1.ØØØ	2.945
7.5ØØ	1.Ø2Ø	2.621
8.ØØØ	1.ØØØ	2.175
9.ØØØ	1.28Ø	1.659
9.5ØØ	Ø.32Ø	1.454

$$pr7 = (Ø.Ø115331r^2 - Ø.Ø53Ø2575r + Ø.145552)^{-1}$$



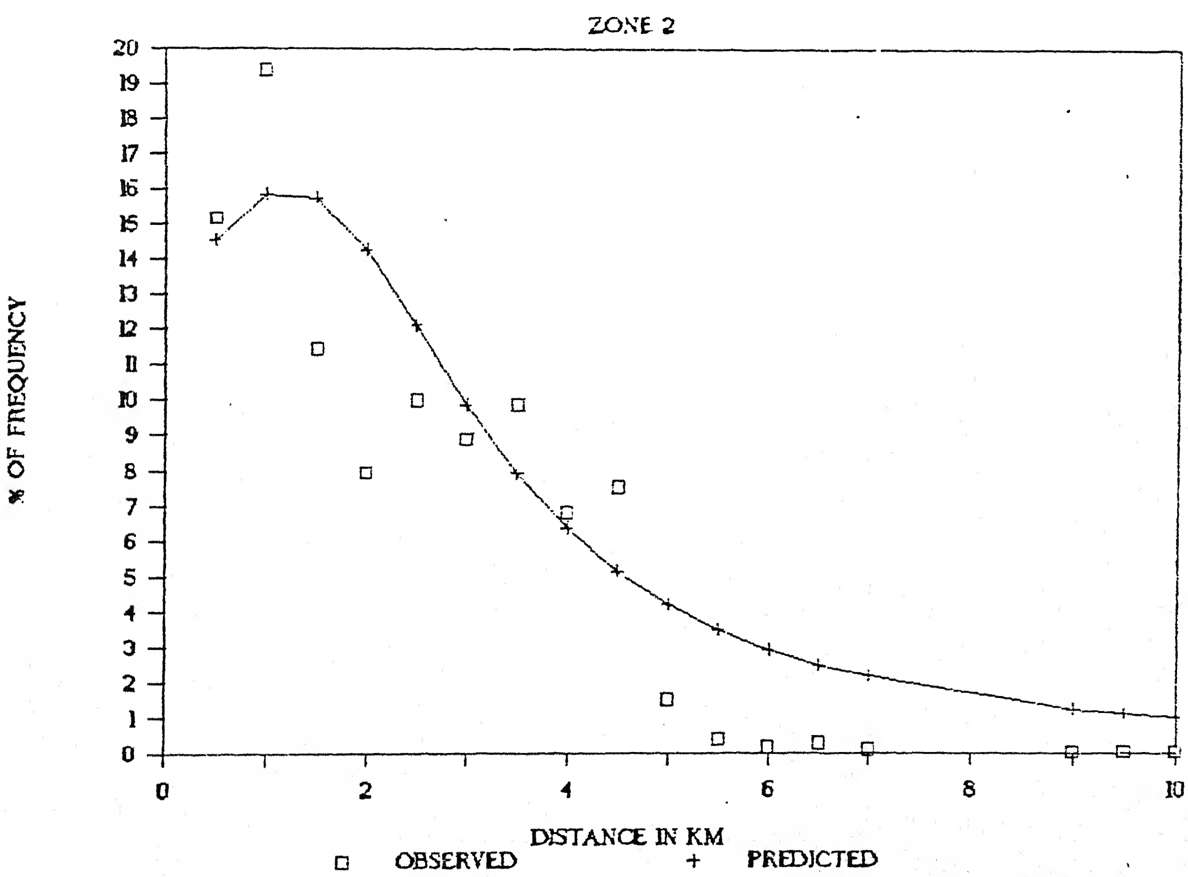
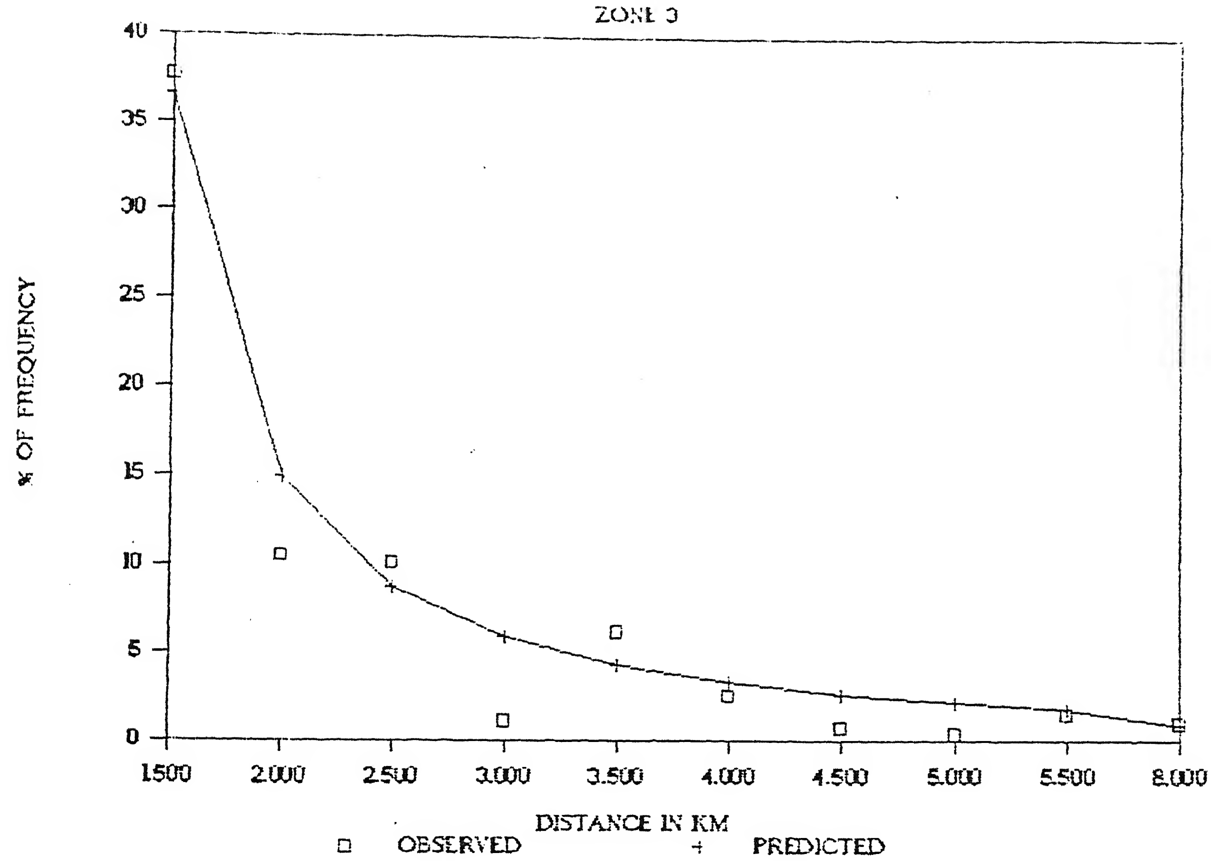


FIG. 4.17 Calibration of College Trip Zone 1 and 2



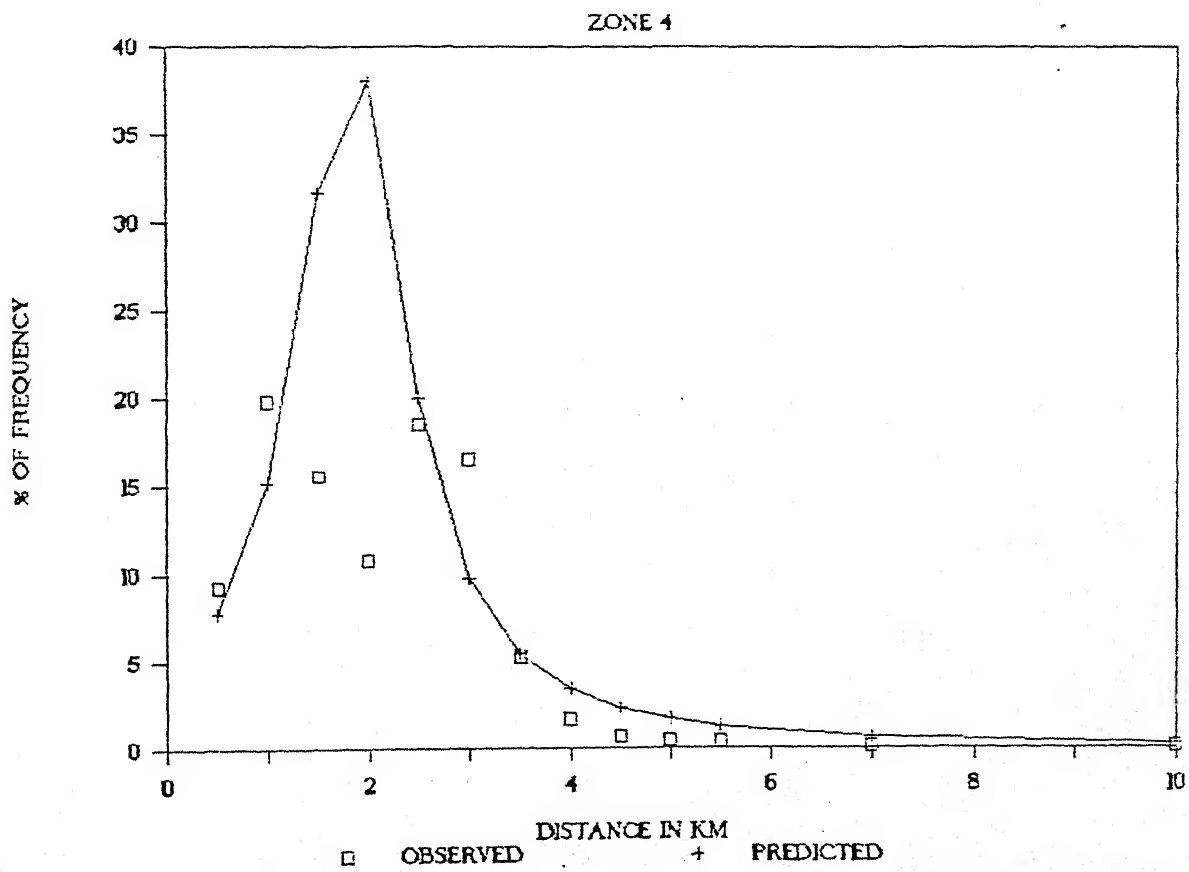
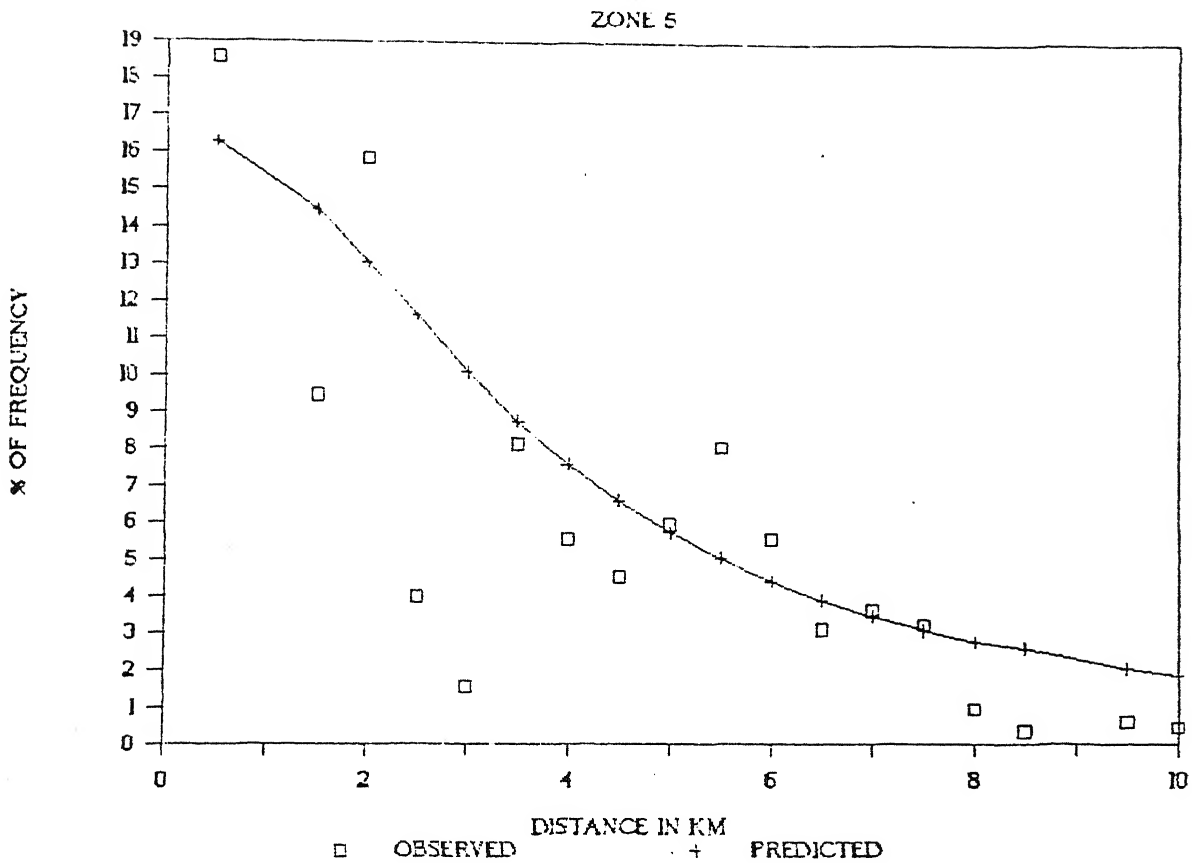


FIG. 4.18 Calibration of College Trip Zone 3 and 4



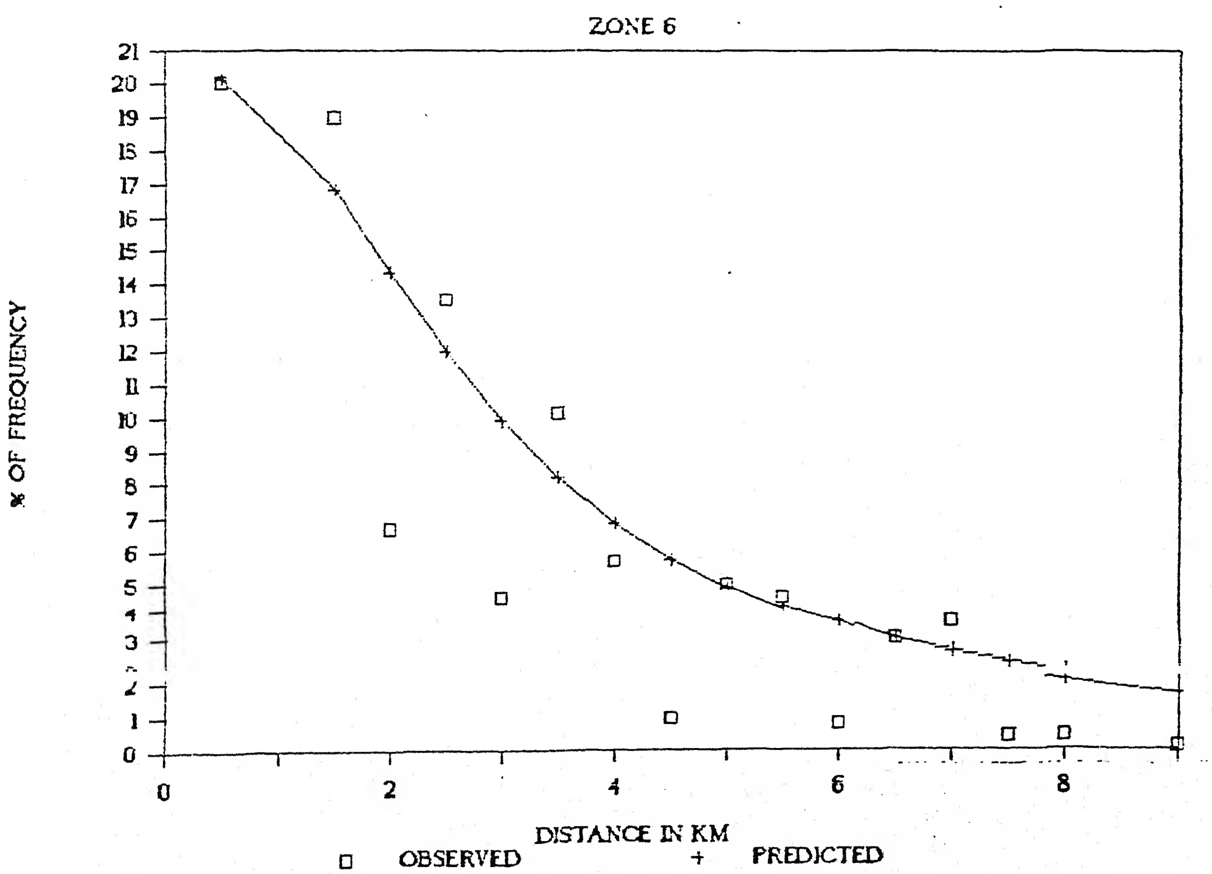


FIG. 4.19 Calibration of College Trip Zone 5 and 6

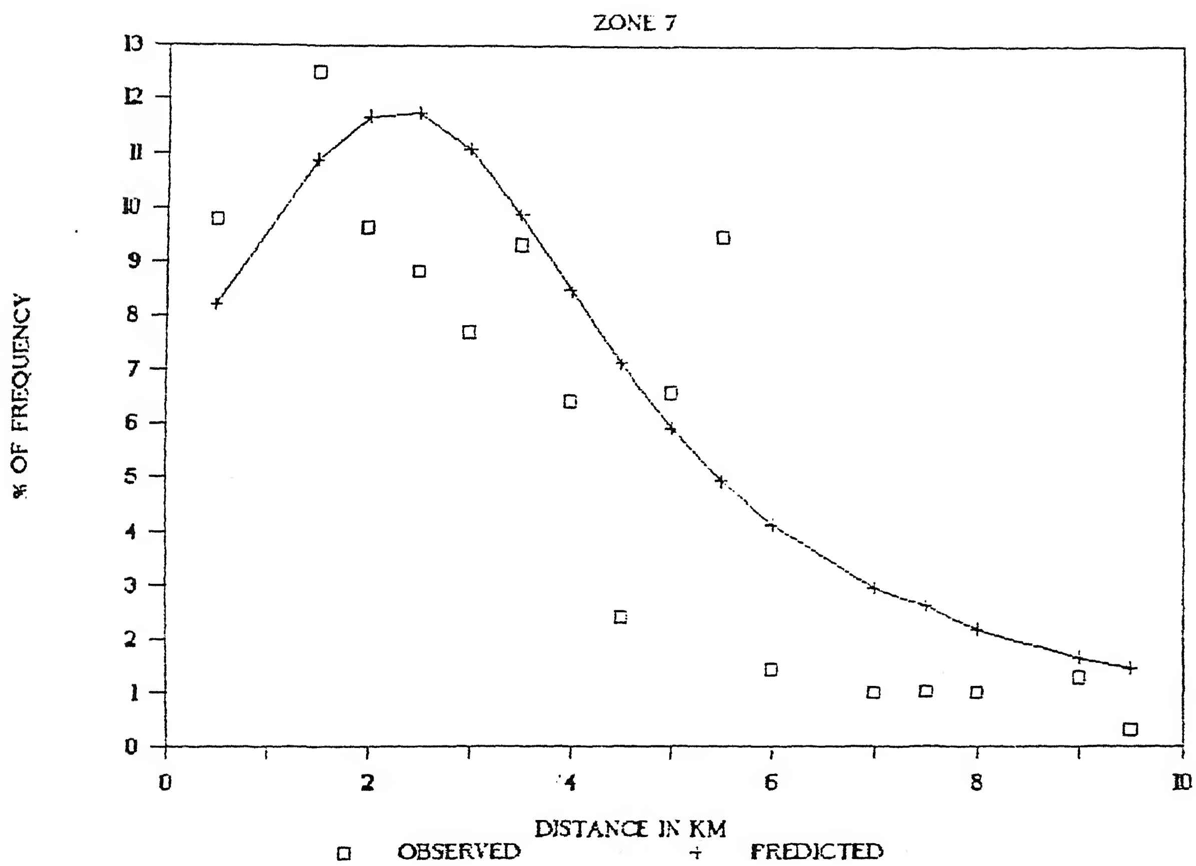


FIG. 4.20 Calibration of College Trip Zone 7

Table 4.15 Observed vs predicted frequency of trip for professional services

Zone 1			Zone 2		
Dist r in Km	Observd	Predictd 'pr1'	Dist r in Km	Observd	Predictd 'pr2'
0.500	12.629	12.087	0.500	28.167	22.825
1.000	10.876	10.803	1.000	12.678	17.318
1.500	8.089	9.656	1.500	5.854	13.139
2.000	7.611	8.630	2.000	10.685	9.968
2.500	4.918	7.713	2.500	7.947	7.562
3.000	10.890	6.894	3.000	11.738	5.737
3.500	3.864	6.162	3.500	7.249	4.352
4.000	7.730	5.507	4.000	3.618	3.302
4.500	4.667	4.922	4.500	1.304	2.505
5.000	12.646	4.399	5.000	0.698	1.900
5.500	5.386	3.932	5.500	1.274	1.441
6.000	0.468	3.514	6.000	1.850	1.093
6.500	2.225	3.141	6.500	2.881	0.829
7.000	1.639	2.807	7.000	1.031	0.629
7.500	1.639	2.509	7.500	0.394	0.477
8.000	2.108	2.243	8.000	0.485	0.362
8.500	1.171	2.004	8.500	0.243	0.274
9.000	0.351	1.791	9.000	0.455	0.208
10.500	0.117	1.279	9.500	0.646	0.158
12.500	0.351	0.816	10.000	0.273	0.120
13.000	0.117	0.729	10.500	0.334	0.091
13.500	0.117	0.652	11.000	0.182	0.069
14.000	0.200	0.582	11.500	0.303	0.052

$pr1 = (13.5238\ e^{-0.224577r}$

$pr2 = (30.0908\ e^{-0.7554331r}$

Table 4.16 Observed vs predicted frequency of trip for professional services

Zone 3			Zone 4		
Dist r in Km	Observd	Predictd 'pr3'	Dist r in Km	Observd	Predictd 'pr4'
			0.500	47.492	46.338
0.500	27.299	29.277	1.000	15.422	19.157
1.000	24.526	20.057	1.500	8.337	7.920
1.500	12.993	13.745	2.000	7.668	3.274
2.000	8.321	9.427	2.500	4.706	1.353
2.500	5.225	6.452	3.000	2.031	0.559
3.000	4.525	4.429	3.500	2.341	0.231
3.500	1.314	3.035	4.000	2.389	0.095
4.000	1.606	2.080	4.500	1.792	0.039
4.500	2.044	1.426	5.000	1.290	0.016
5.000	1.898	0.977	5.500	0.621	0.006
5.500	1.752	0.670	6.000	0.430	0.002
6.000	0.730	0.459	6.500	0.263	0.001
6.500	1.168	0.314	7.000	0.143	0.001
7.000	0.146	0.215	7.500	0.079	0.000
8.000	0.438	0.101	8.000	0.932	0.000
8.500	1.460	0.059	8.500	0.860	0.000
9.000	0.876	0.047	9.000	1.314	0.000
9.500	1.898	0.032	9.500	0.693	0.000
10.500	0.730	0.105	10.000	0.334	0.000
11.500	0.438	0.007	10.500	0.334	0.000
12.000	0.146	0.004	11.000	0.024	0.000
			11.500	0.143	0.000
			12.500	0.024	0.000

$$pr3 = (42.714\ e^{-0.755433r}$$

$$pr4 = (112.0831\ e^{-1.76548r}$$

Table 4.17 Observed vs predicted frequency of trip for professional services

Zone 5			Zone 6		
Dist r in Km	Observd	Predictd 'pr5'	Dist r in Km	Observd	Predictd 'pr6'
0.500	19.828	13.152	0.500	21.857	19.925
1.000	5.444	11.475	1.000	16.593	16.379
1.500	6.280	10.011	1.500	14.583	13.454
2.000	6.430	8.735	2.000	7.413	11.058
2.500	5.785	7.621	2.500	5.057	9.098
3.000	8.324	6.649	3.000	6.096	7.479
3.500	8.000	5.801	3.500	6.100	6.148
4.000	5.419	5.061	4.000	6.187	5.054
4.500	6.086	4.416	4.500	4.810	4.154
5.000	6.323	3.852	5.000	4.919	3.415
5.500	4.495	3.351	5.500	5.092	2.807
6.000	2.688	2.932	6.000	5.507	2.307
6.500	1.505	2.558	6.500	4.600	1.897
7.000	1.677	2.232	7.000	1.663	1.282
7.500	4.043	1.947	7.500	0.312	1.282
8.000	1.269	1.699	8.000	0.831	1.053
8.500	0.237	1.482	8.500	0.450	0.866
9.000	0.817	1.293	9.000	0.345	0.712
10.500	1.097	0.859	10.500	0.277	0.585
11.000	0.366	0.749	11.000	0.381	0.395
11.500	0.215	0.653	11.500	0.410	0.325
12.000	0.065	0.570	12.000	0.208	0.257
12.500	0.129	0.497	12.500	0.069	0.219
13.000	0.086	0.434	13.000	0.139	0.180
13.500	0.086	0.379	13.500	0.104	0.148
14.000	0.043	0.330	14.000	0.173	0.100

$$pr5 = (15.07522\ e^{-0.2728467r}$$

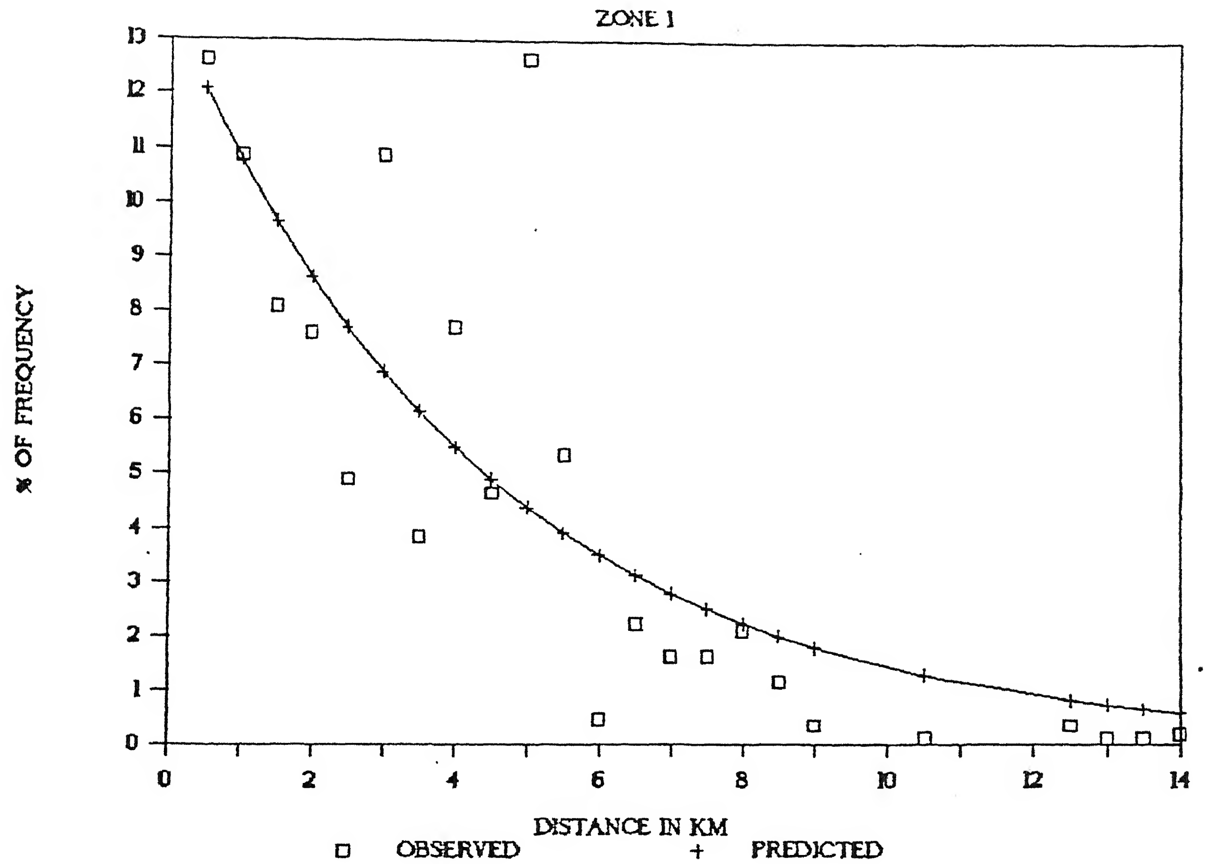
$$pr6 = (24.23874\ e^{-0.3919301r}$$

Table 4.18 Observed vs predicted frequency of trip for professional services

Zone 7

Dist r in Km	Observd	Predictd 'pr7'
Ø.5ØØ	15.Ø33	14.312
1.ØØØ	12.411	12.365
1.5ØØ	7.447	1Ø.684
2.ØØØ	8.518	9.231
2.5ØØ	9.298	7.975
3.ØØØ	5.965	6.891
3.5ØØ	1Ø.298	5.953
4.ØØØ	6.532	5.144
4.5ØØ	5.184	4.444
5.ØØØ	2.695	3.84Ø
5.5ØØ	5.325	3.318
6.ØØØ	2.411	2.856
6.5ØØ	2.Ø57	2.476
7.ØØØ	Ø.7Ø9	2.14Ø
7.5ØØ	Ø.851	1.849
8.ØØØ	Ø.7Ø9	1.597
8.5ØØ	Ø.426	1.38Ø
9.ØØØ	Ø.142	1.192
1Ø.5ØØ	Ø.Ø71	Ø.769
11.ØØØ	Ø.Ø89	Ø.664
11.5ØØ	Ø.142	Ø.574
12.ØØØ	Ø.284	Ø.496
13.ØØØ	Ø.284	Ø.37Ø
13.5ØØ	Ø.7Ø9	Ø.32Ø

pr7 = (15.55484 $e^{-Ø.2923484r}$



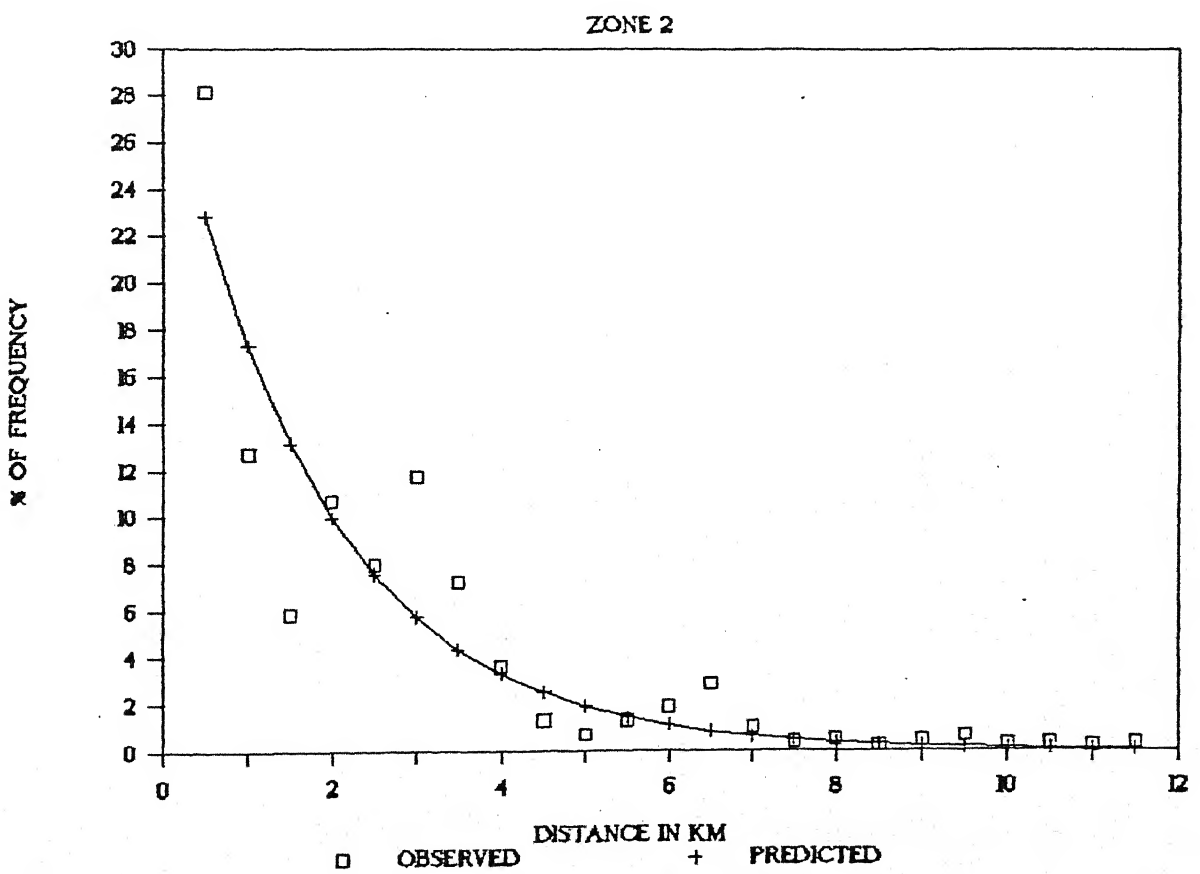


FIG. 4.21 Calibration of Professional Trip Zone 1 and 2

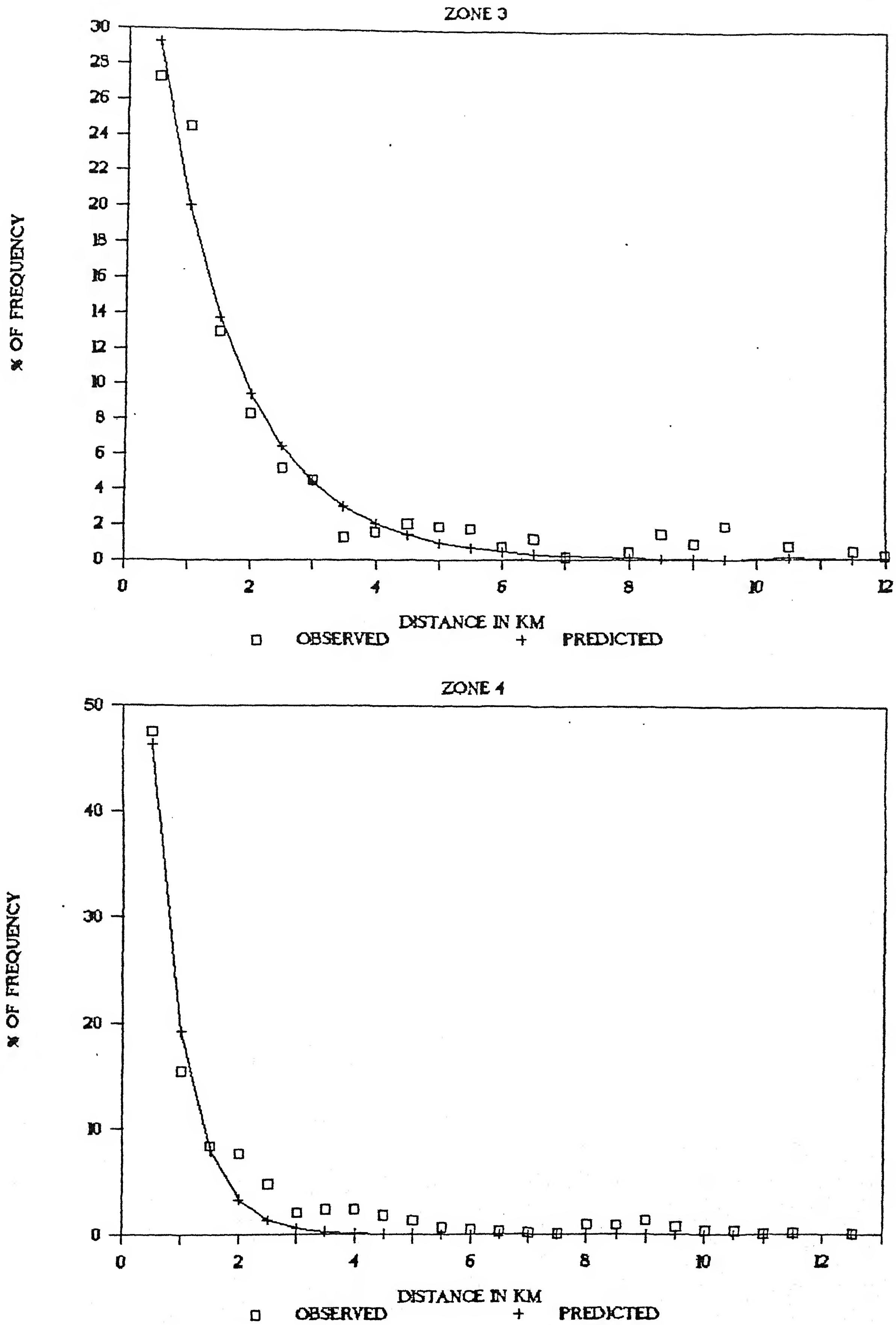
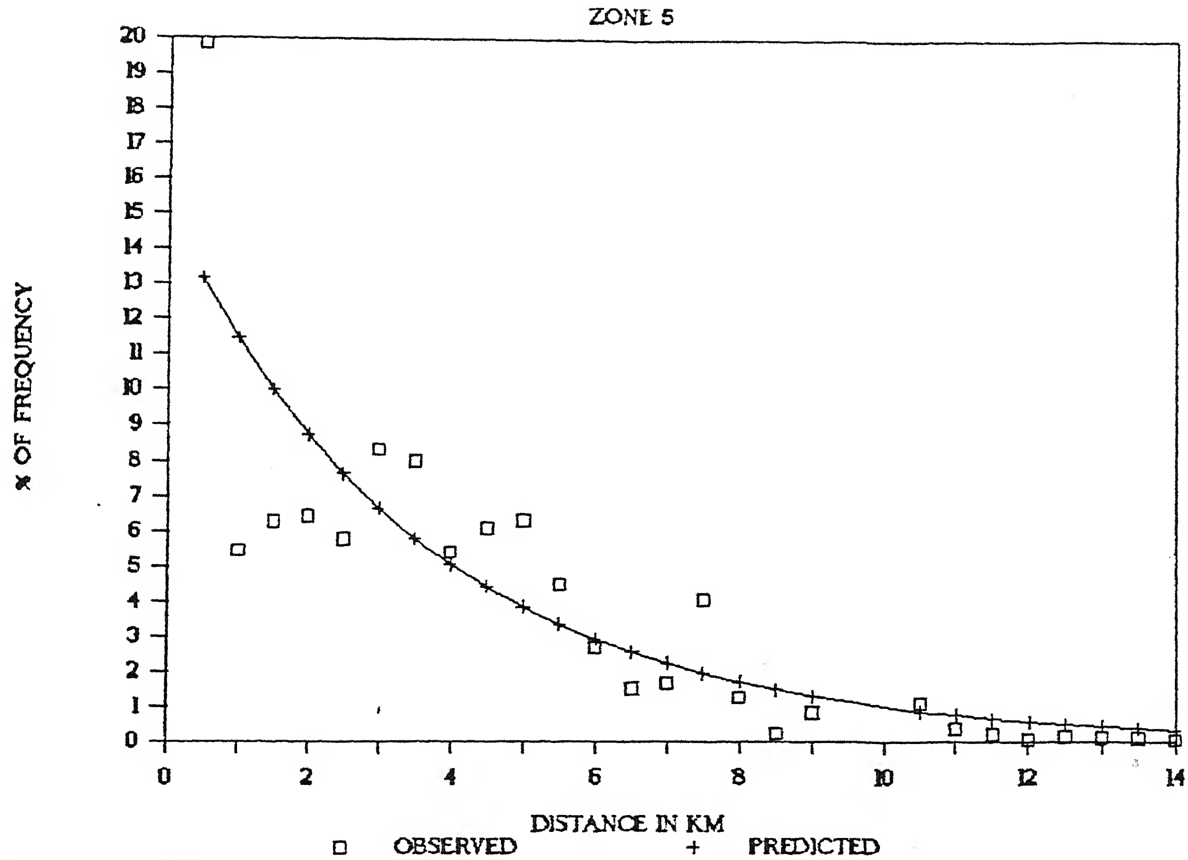


FIG. 4.22 Calibration of Professional Trip Zone 3 and 4



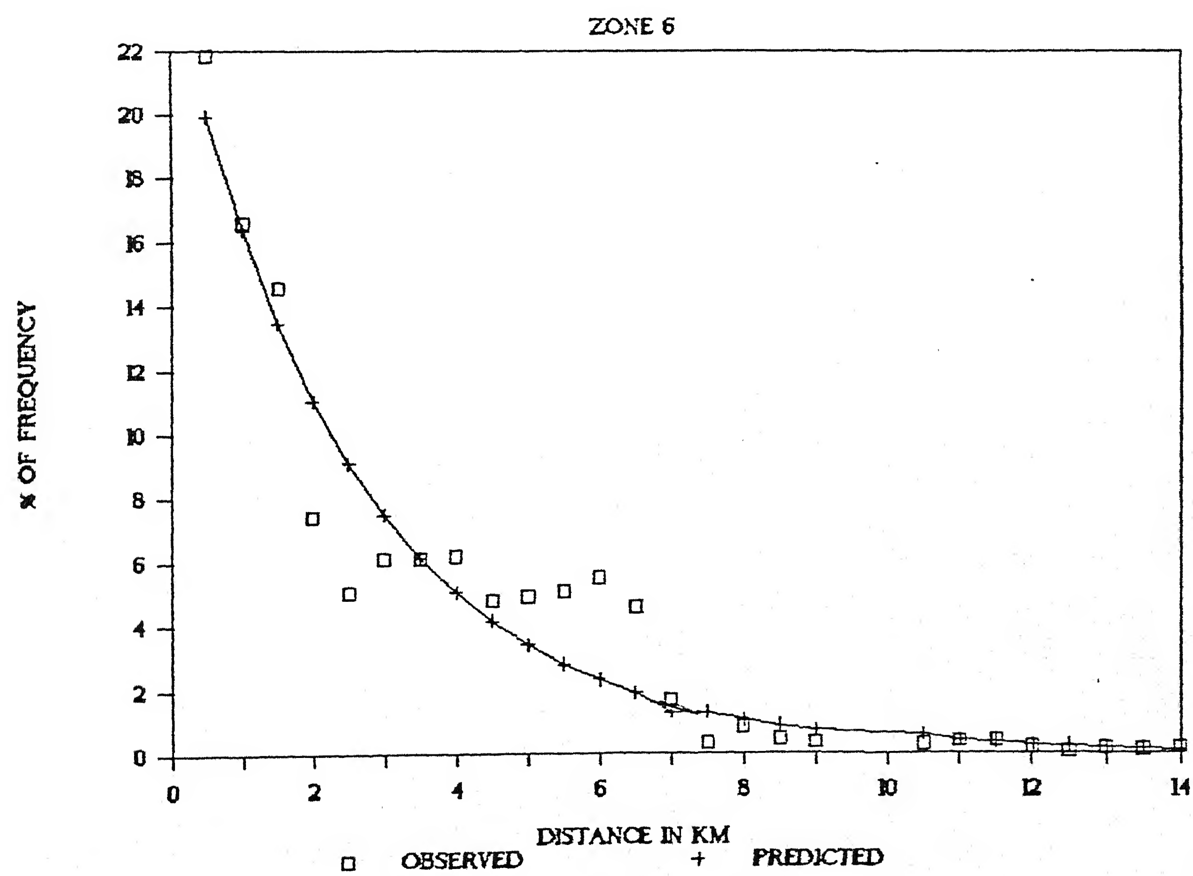


FIG. 4.23Calibration of Professional Trip Zone 5 and 6

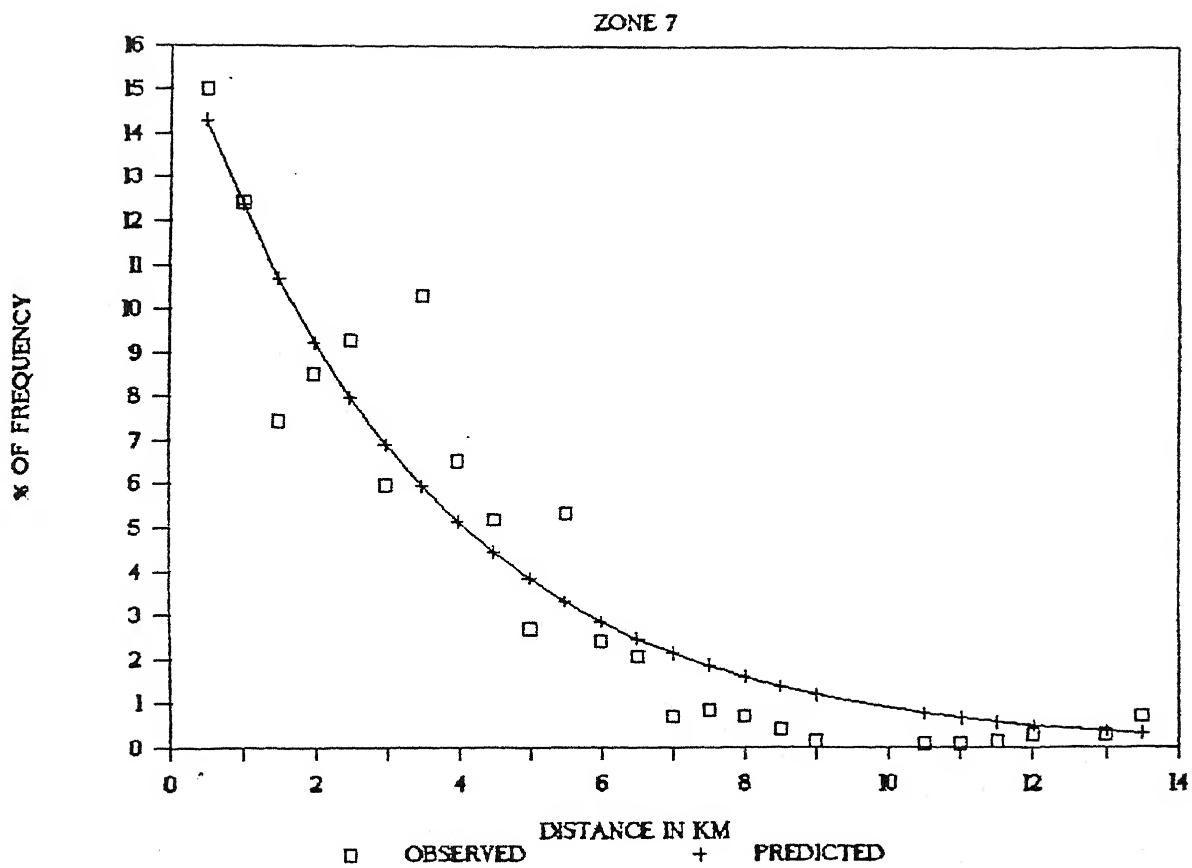


FIG. 4.24 Calibration of Professional Trip Zone 7

The control device chosen was a minimum size constraint, imposed on the distribution of employment for each kind of business. The constraint defines the minimum size (number of employees) of a cluster composed of various kinds of business, service establishments and public agencies.

In this thesis work, since the size and population of each chak differs to one another, a constant value can not be assigned. Based on population, size of a chak, activities different threshold value is assigned. For the neighbourhood sector, a constant value of 8 employees/100 households is found suitable. For the local sector, metropolitan service, after analyzing the home-interview data available and referring telephone directory of Kanpur, a constraint of size varying 50 to 500 for local, 300 to 5000 per for metropolitan are found feasible. One thing to note that each chak has different minimum number of employees constraint instead of agglomeration of services dispersion type is assumed i.e. what have been seen in actual.

Type of cluster	**Minimum number of employees**
Neighbourhood facilities	10 to 100
Local facilities	50 to 500
Metropolitan facilities	300 to 5000

The precise values assigned to the constraints are not crucial. Once the model has allocated the service activity, this is considered as a provisional solution which is tested against the minimum size constraint Z^k. The zone with the smallest

service value which does not satisfy the constraint has its retail employment level set to zero and the service activity in all other zones is rescaled (increased). This process is repeated until the retail employment in all the zones is zero or satisfies the minimum size constraint.

4.5.5 Maximum Density Constraints Z^H

In order to prevent the model from generating excessive population densities in the vicinity of major employment centres limiting values are determined outside the model, and imposed as constraints in the allocation process. These constraints are expressed as maximum number of households per square km. for residential use, and may vary from zone to zone.

Every time the model allocates a given number of households, to a zones, its total is tested against the maximum density constraints, Z_j^H. In all cases in which this constraint is not satisfied, the excess population of the 'saturated' zone is distributed among all other tracts in proportion to their population potentials.

In this thesis work maximum density constraint per chak varies from 1400 household/sq.km to 30000 household/sq.km as per the Kanpur Development Authority report.

4.5.6 Labour Force Participation Rate

The number of households to be located in the area is determined inside the model as a function of the number of jobs

available. This function may be interpreted roughly as a labour force participation rate: the average number of workers per household.

As per the socio-economic and travel characteristics available at the centre for Transportation Engineering and Management at Indian Institute of Technology, Kanpur value is 1.6, i.e. if we take 1Ø households then there will be at least 16 workers on the average.

4.5.7 Retail Employment Coefficient

After the model has evaluated the market potential of each tract, it allocates employment in the appropriate category of retail trade among all tracks in proportion to their potentials. The amount of employment to be allocated is a function of the aggregate market, i.e. the number of households to be served.

With the help of information obtained from Kanpur Telephone Directory employees of all type of sectors can be found out. Then coefficient was determined by dividing it by number of households. Retail employment coefficient for each type of cluster can be calculated by simple division.

Type of cluster		Retail employment coefficient
Neighbourhood facilities		Ø.Ø8
Local facilities	54439/328438	Ø.16
Metropolitan facilities	1938ØØ/328438	Ø.59

Total household is chak number 1 to 146 = 328438

4.5.8 Retail Land use Coefficients

After retail employment has been distributed among zones, the model sets aside space in each tract to accommodate its retail establishment. The amount of space allocated for each kind of retail activity is a function of the number of employees assigned to the tracts. However, since experimental work within the model has already indicated that retail landuse coefficients were merely nominal per meters, whose values need only be such that the land allocation routine does not interfere with more important business, it did not seem sensible to expend much effort on the conversion problem. Values were chosen so as to satisfy served conditions of significance to the model, without much expectation that the resulting spatial distribution of retail land use would have a close resemblance to reality.

In this work, retail land use coefficient are determined as follows. Randomly selected chaks were used for a thorough investigation as to how much land or site area is utilized for neighbourhood, local and metropolitan facilities. After getting the total site areas for each facility, and number of employees engaged in for metropolitan, local and neighbourhood, we calculate the coefficient by dividing area by the number of employees. One thing to note that the site for metropolitan will be smaller than local or neighbourhood because, It is due to the strute of the metropolitan facilities, i.e. most of them are

functioning in a multi-storied buildings. The percentage of area alloted to industrial, public and semi public is 18% of total area in Kanpur.

The landuse coefficients finally used in the experiment are the following.

Type of cluster	Sq.km per employee
Neighbourhood facilities	0.0001
Local facilities	0.00005
Metropolitan facilities	0.000025

4.5.9 Shopping trip weight factor related to class k, c^k & d^k

The factors indicate the level of influence of the interaction between retail houses and households and between services and employees respectively. Having studied carefully the non-home based, home based trips in each chak for each category is local, metro. The proportions used in the model are given below.

	c^k	d^k
Neighbourhood	0.90	0.10
Local	0.70	0.30
Metropolitan	0.50	0.50

Parameters for Retail facilities

Description	Neighbourhood	Local	Metropolitan
Total Service employment	26276	52552	197070
Minimum employees per chak	30	250	500
Number of households necessary to support one employee	12.5	6.25	1.7

4.6 Solution of the system

Having determined all the parameters used in the Lowry model, the model is simulated. The solution procedure adopted is the same as that described at step one to step three in chapter three. A Fortran programme is used to solve the model. An iterative procedure adopted the values of the diffrerent variables obtained during the iteration are calculated. The total household N is estimated using the following equation.

$$E_j = E^B{}_j + \sum_{k=1}^{m} E^k{}_j$$

$$N = f \sum_{j=1}^{n} E_j$$

The total households N used by the model as an independent variable is compared with the total households N^* predicted by the model. If they are different, the derived values obtained during the iteration are fed back as independent variables and the model is run in this iterative fashion until they converge on a stable value. The table gives the iterations and household number in each iteration using a T_{ij} function $20.8e^{-0.377r}$.

4.7 Results

After about 10 iterations the total number of households converge to 338060. The table 4.18 A given below

Table 4.18 A Iteration vs number of households

Iteration	Employment	Number of households
1.	263020	157235
2.	387234	241427
3.	453746	282398
4.	486112	301704
5.	501365	316782
6.	518537	315108
7.	527709	327147
8.	537822	333853
9.	543455	337066
10.	544469	338060

4.8 Validity of Model

The output from the model is tested with actual data. This is made in two ways.

(a) Comparison of observed and predicted households and

(b) Comparison of observed and predicted service employment.

4.8.1 Comparison of observed and predicted households

This can be conducted in two ways:

(1) A graph is drawn with observed and predicted households along the axes. Then a line is drawn making an angle 45° with X-axis. If the model is perfect all points of the graph will be lying on the line. How best the model is can be ascertained by closeness of each point to the line. Table 4.19 gives the households comparison when different T_{ij} function are used.

Table 4·19

Chak No	Actual households	Predicted households by pr1	pr2	pr3
1	1990	2003	2017	2004
2	2980	3063	3064	3078
3	2257	2385	2386	2381
4	1030	923	924	1047
5	758	552	553	759
6	698	777	771	896
7	1522	1559	1560	1557
8	2829	3000	3003	2992
9	1729	1792	1797	1784
10	3354	3527	3602	3514
11	2991	3337	3342	3307
12	3797	4155	4100	4124
13	2284	2504	2501	2488
14	1459	1427	1425	1417
15	1783	2047	2044	2032
16	724	749	747	748
17	897	1351	1339	1330
18	678	1497	1482	1464
19	995	1349	1055	1349
20	1057	763	646	703
21	490	506	494	500
22	653	810	751	795
23	559	870	860	867
24	1190	433	240	369
25	372	1112	1079	1077
26	41	0	0	0
27	699	376	400	325
28	1054	1005	975	966
29	599	706	674	696
30	1110	1153	1084	1144
31	874	3456	3213	3420
32	1350	1602	1386	1543
33	1431	675	330	555
34	590	603	566	596
35	1116	1836	1787	1825
36	787	730	578	697
37	340	1140	1104	1104
38	1386	2566	899	2486
39	341	764	739	745
40	130	272	259	265
41	512	907	881	888
42	685	1397	821	1363
43	1322	1206	1202	1203
44	1596	1426	1309	1372
45	670	798	745	764
46	782	1074	1018	1072
47	612	631	630	607
48	139	369	279	292
49	623	1035	1025	1009
50	1653	1498	1032	1398

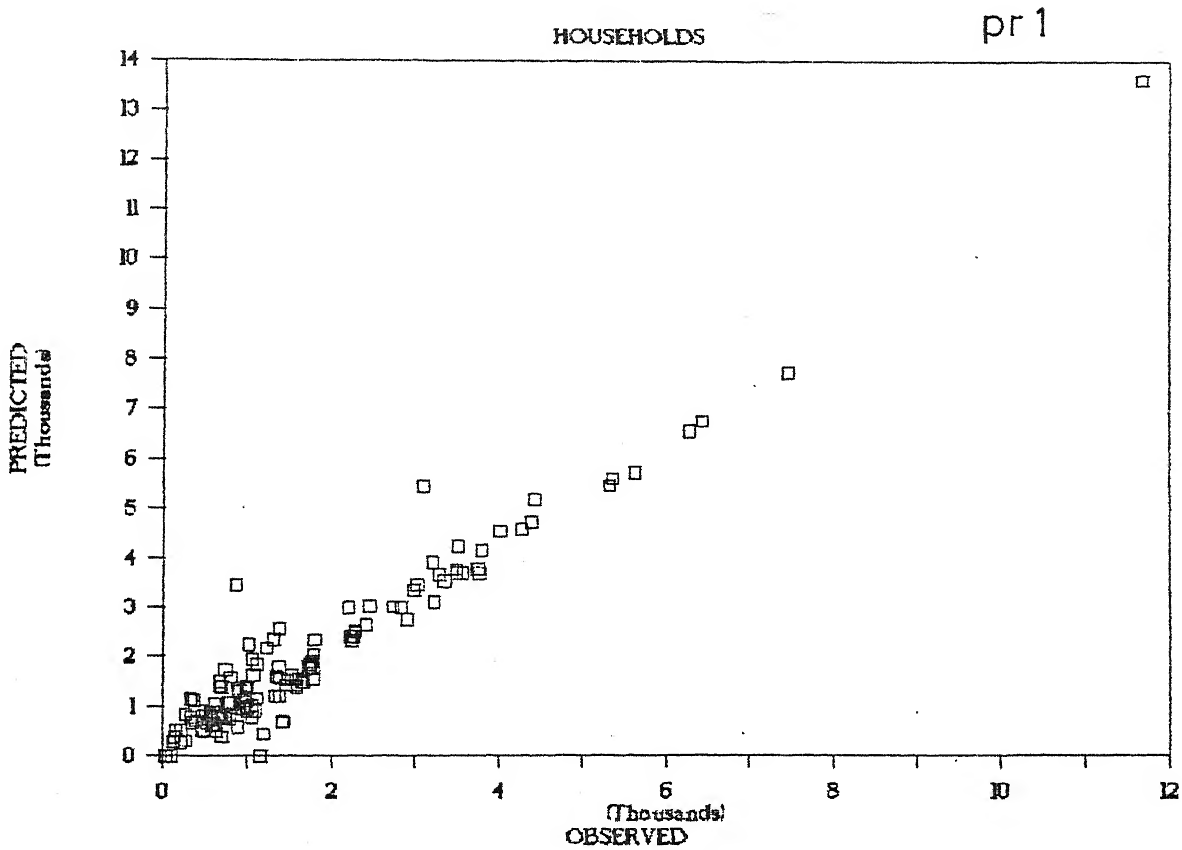
Chak No	Actual households	Predicted households by pr1	pr2	pr3
51	533	666	193	631
52	224	264	263	255
53	165	507	507	493
54	271	828	821	804
55	600	886	868	856
56	700	1383	1327	1313
57	918	1307	1306	1301
58	803	1585	3657	1443
59	1003	890	3310	751
60	400	698	806	689
61	1101	905	929	852
62	1374	1786	1791	1782
63	595	775	751	765
64	1587	1392	1692	1377
65	1471	1537	1548	1533
66	1669	1475	1505	1457
67	557	859	857	826
68	976	1053	1129	289
69	1417	692	1639	665
70	645	496	496	488
71	1236	2179	4252	2010
72	110	0	0	0
73	266	301	302	299
74	1381	1201	1209	1173
75	219	497	495	483
76	2207	3008	2864	2891
77	742	1736	977	1685
78	1742	1845	1767	1796
79	980	1386	1356	1362
80	993	980	949	942
81	1073	1620	1613	1557
82	660	773	779	767
83	3494	3696	3696	3681
84	3575	3697	3699	3692
85	2458	3025	3023	2992
86	3207	3912	3915	3855
87	1769	1886	1829	1876
88	4023	4542	4555	4500
89	1794	2336	2296	2286
90	1158	0	0	0
91	741	803	785	790
92	1300	2354	2336	2336
93	1016	2253	2224	2229
94	473	790	764	775
95	978	1171	1131	1139
96	1068	1948	1868	1896
97	1378	1567	1522	1535
98	890	586	552	560
99	1779	1544	1604	1527
100	2912	2744	2737	2705

Chak No	Actual households	Predicted households by pr1	pr2	pr3
101	2740	3010	2983	2961
102	799	1068	1071	1050
103	3090	5436	5484	5423
104	3775	3693	4011	3955
105	6287	6543	6574	6525
106	3237	3107	3316	3107
107	360	650	713	650
108	1569	1545	1815	1479
109	3294	3654	3953	3630
110	1778	1755	1960	1685
111	3034	3453	3485	3435
112	2268	2411	2418	2401
113	1529	1638	1641	1633
114	481	511	511	515
115	800	812	812	812
116	955	956	956	967
117	3756	3786	3786	3783
118	4400	4718	4735	4691
119	696	758	763	753
120	2238	2322	2324	2316
121	3500	3758	3759	3743
122	6435	6742	6743	6722
123	4428	5167	5169	5117
124	5335	5452	5480	5462
125	2230	2407	2404	2387
126	2285	2515	2511	2490
127	11680	13618	14222	9430
128	5370	5582	5580	5575
129	5640	5717	5719	5711
130	3510	4230	4240	3920
131	2420	2643	2645	2648
132	4280	4586	4589	4583
133	7460	7716	7716	7772
R^2		0.9091	0.8610	0.8562

$$Pr1 = 20.8e^{-0.371r}$$

$$Pr2 = 14.87r^{-0.825}$$

$$Pr3 = (0.0223r^2 - 0.0609r + 0.0101)^{-1}$$



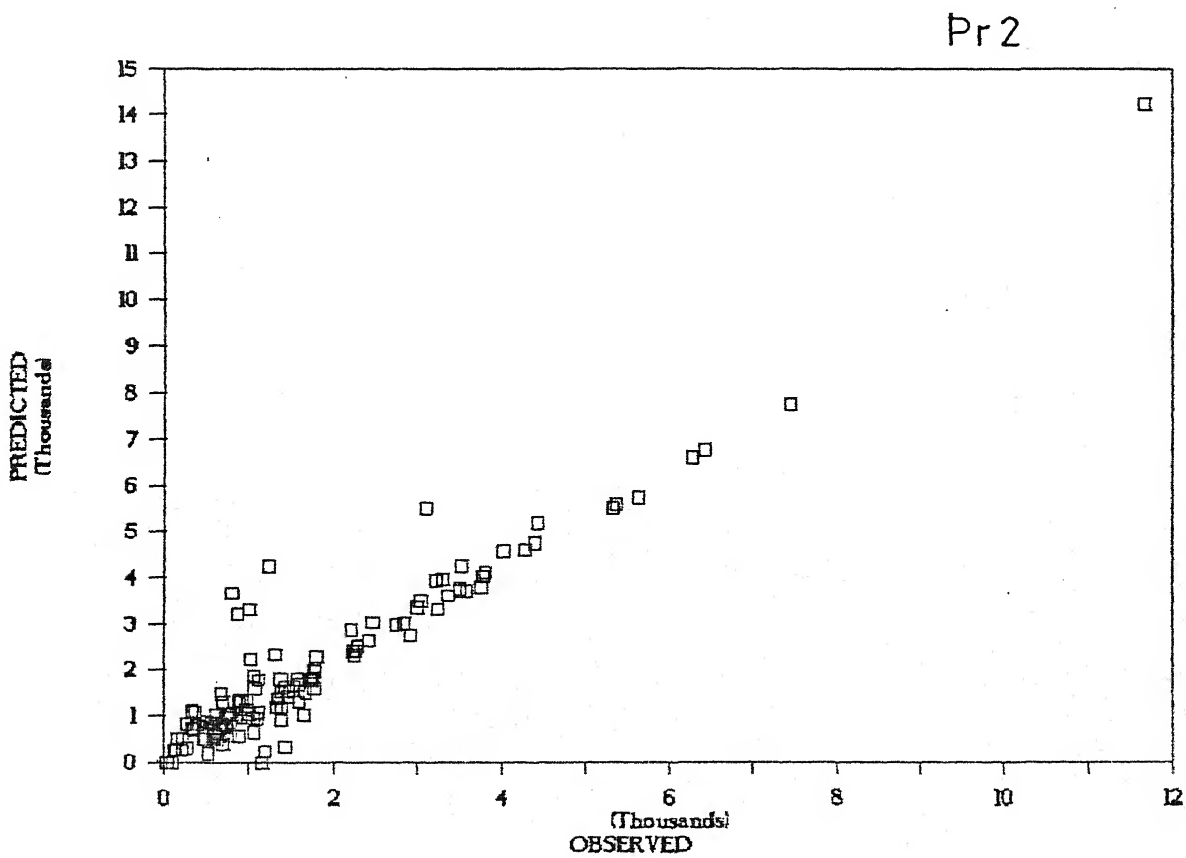


FIG. 4.25 Observed vs Predicted Household

The predicted households using different trip distribution functions are evaluated in which households predicted by a trip function of $20.8e^{-0.377r}$ gives the maximum coefficient of determination. ($R^2 = 0.9091$)

4.8.2 Comparing with Service Employment

Here the validity of service employment is checked against coefficient of determination. The table 4.20 gives the observed versus predicted service employment zonewise.

Table 4.20

Zone No	Observed Employment	Predicted by the T_{ij} function of		
		Pr1	Pr2	Pr3
1	7520	6493	5106	6236
2	17256	13501	14015	29193
3	14185	13852	14641	13606
4	126900	141900	142750	177258
5	17475	19429	20943	21258
6	15832	16840	16420	21258
7	8948	7746	7510	9312

$Pr1 = 20.8e^{-0.377r}$ $R^2 = 0.9535$

$Pr\ 2 = 14.87r^{-0.825}$ $R^2 = 0.9193$

$Pr\ 3 = (0.02235r^2 - 0.6098r + 0.1015)^{-1}$ $R^2 = 0.8810$

The above table indicates that if a T_{ij} function of $20.8e^{-0.377r}$ is chosen for the prediction spatial distribution of Kanpur, it gives a better output which suits the Kanpur's present condition best.

CHAPTER 5

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

5.1 Interpretation

1. As far as metropolitan cluster trips are concerned, more than 50% of the trips have occurred within a range of 2.5 km. Remaining 50% will be scattered at a range from 2.5 km to 15 km.

2. It is interesting to note that more than 70% of the metropolitan trips in zone 4 is made within 2 km, Interestingly zone 4 belongs to a CBD. It is obvious that people living in CBD are having minimum trip lengths.

3. A zone having longer trip length indicates that there are more trip productions. In other words,it belongs to residential area. This conclusion is supplemented by zones 5,6 and 7 which are having longer trip lengths. As far as residential density is concerned these zones are having higher density as compared to other zones.

4. Another very interesting factor is that, compared to zones 3 and 4 (Easternside of Kanpur), zone 6 and 7 (Westernside) have a well distributed travel pattern. It indicates that people at Kanpur prefer to live on the westernside rather than on the easternside. In other words Kanpur is developing towards westernside than easternside.

5. Metropolitan trips reveal that people are not sensitive to 1Ø to 15 minutes traveling time.

6. A chak having good basic employment is found to be surrounded by other chaks having good residential density. This is emphasized by the fact that chak 14 which has many textile mills is circumscribed by the other chaks 13,15 and 16 having a high density population.

7. Another very interesting factor is the professional trip distribution in zone 4, whose trip elasticity is 1.76548. It indicates that distance to be traveled by people living in zone 4 is very less compared to other zones. Zone 4 is the only area where this elasticity is seen more than unity. Note that the elasticity of trips in zone 1 and 5 are Ø.224 and Ø.2728 respectively. It shows that people in the zones 1 and 5 have to travel a longer distance to reach their respective workplace. In zone 4, the professional people live very near their workplace.

8. Zone 3 comaparitively has a lesser school trip length. It indicates that there are a sufficient number of good schools, (in all media) available very near to their residence. As per data it is correct.

9. Considering college education the trip lengths are found to be upto 8km. When we consider the actual data of college trip,there is a high fluctuation in % of trip with distance. It indicates that there are only limited number of colleges offering all types of courses like arts,science and commerce.

5.2 Observations

(1) As the area of chak varies from Ø.9 sq km to 55 sq km, giving a minimum constraint for the service sector is extremely difficult.

(2) Data had been collected only for chaks from 1 to 133. The socio-economic properties of chak from 134 to 146 are assumed to be the same as that of the adjacent chak.

(3) So far no authority had taken any strain to find the retail employment coefficient(a^k) and retail employment density ratio (c^k). It is very difficult to get these values unless a tremendous amount of manpower is used.

(4) When the test was conducted without any constraint it was found that more and more people would prefer to live in or open shops in Zone 4(note that it is actually the central business district).

(5) As far as the population density constraint is concerned, allmost all the chaks are saturated, the only regions that are not saturated are the outer boundaries.

(6) The labour force participation ratio is to be correctly chosen. The impact of unemployment can be predicted by lowering the labour force participation ratio. Participation of women in the labour force can be predicted by increasing labour force participation ratio. Since the Lowry model is a static model, it predicts only the demand. So most of its prediction about

households and employees are likely to be overestimates.

5.3 Suggestions

There is a need to improve the data base for the landuse transportation planning studies in a way which takes account of the range of socio-economic grouping and households structures. Sampling rate for the households travel surveys compatible with the socio-economic groupings are required to be developed for the different classes of town and cities. More accurate data on employment and disaggregation by income groups should be developed.

For a better understanding of the urban system, it is desirable to study the travel patterns of the urban resident in various socio-economic disaggregated groups. Educational, social and recreational trips which form a significant proportion of the total trips require more detailed investigations as well.

To improve the operation of the model and to develop a policy which is sensitive to transportation variables a behavioral mode split technique is very essential to start with. This will incidentally eliminate the spatial disaggregation at calibration stage.

5.4 Further study

(1) If there are more classifications of service sectors, the better will be the results. i.e. a disaggregation of service sector is recommended.

(2) If the trips distribution coefficient can be determined based on mode, it can be used to schedule the timing of buses and intermediate public transport system. To improve the operation of the model and make its policy more sensitive to transportation variables a behavioral mode split technique is very essential to start with.

(3) Owing to its impact on travel behaviour, a disaggregation of trips based on a socio-economic parameter like income group (high, medium and low) is recommended.

(4) In addition to the accessibility technique for the location of houses and industries, an attraction coefficient can also be incorporated into the model. This can be determined based on plinth area of residence, floor areas of offices or industries etc.

(5) A better spatial allocation will result, if a chakwise analysis is resorted to instead of a zonewise analysis.

5.5 Comment

The distribution of population generated by employment in the various areas are based on the assumption that residents in each area wish to minimize transportation cost; this assumption ignores social values which can influence location behaviour as well as economic market conditions. Lowry model is a demand model which does not incorporate a model of the supply side for houses and other constructions, also it is a static equilibrium model.

One weakness of this model is that it does not take the industrial location as an exogeneous factor.

Another difficulty of model building is that cities are probably in a state of constant nonequilibrium, since there are substantial time lags between cause and effects. Because Lowry's model is not formulated directly so as to simulate the way growth and change actually occur through time, a whole range of further assumptions have to be made; the service centres spring up exactly in order to meet the demand for goods, employees are in equilibrium with the number of jobs and location of work places, all at a single point in time. There is no question of delayed response to particular changes in time or shops lagging behind residential development. The distribution of population generated by employment in the various areas is based on the assumption that residents in each area wish to minimise transport costs, this assumption ignores social values which can influence location behaviour as well as economic market conditions.

The Lowry model despite all its criticism is at present the most widely accepted urban spatial model in practice. Possible unforeseen changes can be tested for their likely impact, for example the establishment of a large new factory, or airport, or a long-term change in activity rate or unemployment.

More interesting and relevant policies affecting different income groups and focusing more directly on specific issues such as particular type of urban renewal, subsides and so on, must

wait for more sophisticated models. As Lowry points out about his model: "Properly adopted, it should be useful for the projection of future pattern of land development and for the testing of public policies in the field of transportation planning, landuse controls, taxation and urban renewal [5].

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